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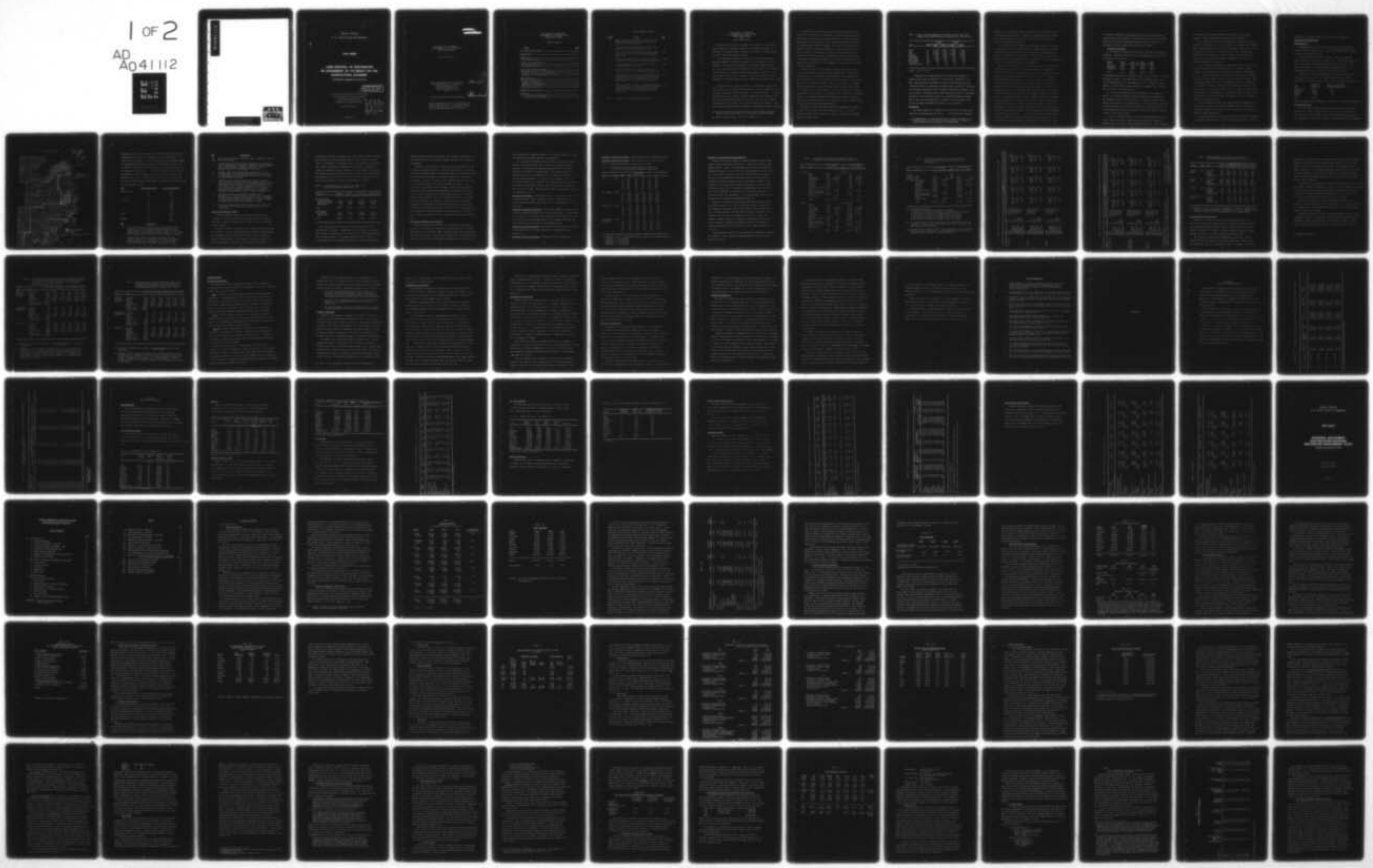

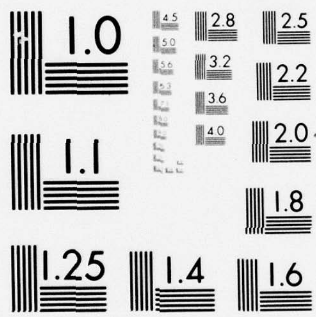

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LAND DISPOSAL OF WASTEWATER AN ASSESSMENT OF ITS IMPACT ON THE AGRICULTURAL ECONOMY.

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NATURAL RESOURCE ECONOMICS DIVISION
ECONOMIC RESEARCH SERVICE
NORTHEASTERN RESOURCE GROUP

Upper Darby, Pennsylvania

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LAND DISPOSAL OF WASTEWATER -- AN ASSESSMENT OF ITS IMPACT ON THE AGRICULTURAL ECONOMY

by

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United States Department of Agriculture
Natural Resource Economics Division
Economic Research Service
Northeastern Resource Group
Upper Darby, Pennsylvania
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LAND DISPOSAL OF WASTEWATER —
AN ASSESSMENT OF ITS IMPACT ON THE
AGRICULTURAL ECONOMY

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LAND DISPOSAL OF WASTEWATER -
AN ASSESSMENT OF ITS IMPACT ON THE
AGRICULTURAL ECONOMY

by
Lee A. Christensen[1]

The Detroit District Corps of Engineers is responsible for developing a regional approach to wastewater management in Southeastern Michigan. An evaluation of alternative means of disposal of wastewater originating within the Detroit metropolitan area is underway.

In the preliminary (feasibility) phase of the Southeastern Michigan Wastewater Management Study, land disposal was one of several alternatives evaluated. The others involved chemical and biological treatment methods. One of the recommendations of the feasibility study was that the full range of emerging treatment technology be further investigated. In addition to the land disposal alternative, this included a study of the technical design and evaluation of ecological, hygenic, social, aesthetic, and economic effects (7)[2].

The Natural Resource Economics Division, Economic Research Service, has direct interest in the land disposal alternative. Part of the NRED mission is to provide assistance in land use planning. It has been involved in two river basin planning efforts within the area; the Great Lakes Basin Framework Study and the Southeast Michigan Water Resources Study. Data from these studies provided agricultural resource base information used in an evaluation of the land disposal alternative within a framework of comprehensive regional planning.

1/ Agricultural Economist, Natural Resource Economics Division, Economic Research Service, Upper Darby, Pa., formerly East Lansing, Michigan.

2/ Bracketed numbers refer to references on page 32.

For the purpose of this report only the proposed land disposal alternatives will be considered. No comparisons or contrasts with other alternatives will be presented. The primary objective is to estimate a range of probable direct economic impacts of the proposed land disposal alternative on the agricultural economy of the area. The concept of economic impact is broad and subject to varied interpretations. As used in this study, the term is intended to include only the direct or first round effect on key variables associated with changes in agricultural production, namely value of production, employment and population. The effect of disposal on interregional shifts in production is not evaluated. Implications for farm organization are explored.

Changes in production from cropland in proposed disposal sites may be viewed in relationship to projected regional requirements. The Economic Research Service and the Bureau of Economic Analysis have estimated total national requirements for food and fiber and allocated shares to major river basins such as the Great Lakes Basin. (For more information on the OBERS projection procedures, see (6).) The Great Lakes Basin share was allocated to 15 subareas, two of which, subareas 4.1 and 3.2, include the four proposed land disposal sites described in a following section. Subarea 4.1 corresponds exactly to the Southeast Michigan Water Resources study area. Subarea 3.2 includes Huron and Tuscola Counties plus Bay, Clare, Genesee, Gladwin, Gratiot, Isabella, Lapeer, Midland and Saginaw Counties.

The shares of Great Lakes Basin requirements disaggregated to Subareas 3.2 and 4.1 for the years 1980 and 2000 appear in Table 1. These are normative estimates which represent the least cost allocation of the Great Lakes Basin requirements.

Table 1: Share of National Requirements Allocated to Great Lakes Basin Subareas with Proposed Wastewater Disposal Sites, 1980 and 2000.

Crop	Unit	Subarea 3.2 1980	Subarea 3.2 2000	Subarea 4.1 1980	Subarea 4.1 2000
		-----------1000 units-----------			
Wheat	bu	15,576	20,749	10,286	11,702
Oats	bu	11,190	9,536	6,367	6,723
Corn	bu	21,803	27,129	24,537	26,608
Soybeans	bu	3,659	5,402	11,833	12,648
Dry Beans	cwt	7,166	9,469	910	1,202
Corn Silage	ton	1,118	1,912	1,121	1,184
Alfalfa Hay	ton	603	773	495	427
Other Hay	ton	71	92	99	67
Cropland Pasture	ton	93	124	19	17

Source: (5, p. 99-100)

A comparison of estimated production from the areas designated as disposal sites "with" and "without" the application of wastewater will be made. Estimates without wastewater are based on land use and crop yield information utilized in existing river basin studies. Estimates of production with wastewater application reflect assumptions dealing with changes in land use and yields. Assumptions must be made concerning the effects of wastewater disposal on soils and yields as there is a recognized shortage of primary data on short and long range effects. Estimates of crop production that reflect alternative assumptions will assist in the evaluation.

Methodology

The areas designated for disposal sites are those in the design report prepared by Dow Engineering, Inc. (3) 1/. Once the area was delineated

1/ Dow Engineering, Inc., Midland, Michigan, is a major consultant to the Corps of Engineers on this study with responsibilities to design the irrigation and collection facilities for land disposal.

estimates of the production capacity of that area "with" and "without" land disposal treatment was possible. Finally, the associated levels of product value, employment and population can be estimated and compared with and without the land disposal treatment.

It was assumed that the disposal sites were representative of the area encompassing them in terms of major land use, cropping patterns, and yields. Consequently, detailed projections of the larger area regarding production and land use patterns that were available in the Great Lakes and Southeast Michigan studies were disaggregated to the disposal sites. Using this approach projections for "without" treatment were estimated.

Data on major land use for the site areas was available from the 1966-67 Conservation Needs Inventory. Using this information, the aggregate land requirements identified by Dow Engineering, Inc. were disaggregated into three categories: 1) cropland and pasture 2) forest, and 3) other. Acreage in cropland and pasture was assumed to be the resource base for production estimates "without" land disposal. The resource base for production with disposal included the land in all three of these categories. Yields and cropping patterns from existing river basin studies were applied to cropland and pasture acreage within the sites. This provided estimates of production from the sites without wastewater disposal. Ranges of production associated with the implementation of disposal were estimated, using the crop rotation specified by Dow, Inc. Five levels of yields were assumed to reflect the uncertainties surrounding soil and crop responses to wastewater applications. The value of agricultural production from the wastewater sites was estimated, using normalized prices (13). Using labor productivity figures, agricultural employment was estimated directly from value of production. Population was then estimated using population-employee relationships. Value

of production, employment, and population "with" and "without" disposal on the proposed site were compared. The alternative levels of production were related to the regional requirements specified within the context of the existing river basin studies, as noted previously in Table 1.

Underlying Assumptions

1. The sources of wastewater are municipal, industrial, and stormwater discharges. Estimated volumes from the Detroit Metropolitan area provided by the Corps of Engineers are:

Source	1970	1980	1990	2000
	(MGD)			
Municipal	426.9	515.2	614.8	714.5
Industrial	1216.7	951.3	828.2	705.0
Stormwater	621.8	621.8	621.8	621.8
Total	2265.4	2088.3	2064.8	2041.3

A land disposal system may be designed to handle all or a portion of the total wastewater discharge. The design volume for four Michigan disposal sites in the Dow Engineering report is 2800 MGD, (3, p. VI-3). Because of limited acreage in the area with the desired permability characteristics, stormwater will be treated by other alternatives.

2. The basic building block of the Dow design is a four square mile module. All irrigation equipment, piping, pumping and other requirements were designed and costed on a module basis. A number of irrigation alternatives were evaluated in the design process. A center pivot system designed to apply a maximum of three inches of wastewater per week was selected. However wastewater applications are expected to average two inches per week for 35 weeks, or 70 inches per year.

3. The total land area required is 597,530 acres distributed over four sites. This is for lagoons, buffer zones, access and service areas and disposal sites. It does not include sludge disposal sites or river corridors.

For comparison purposes land requirements associated with alternative wastewater volumes and application rates are shown in Appendix 1.

4. The quantity of water to be discharged from irrigation sites after renovation is approximately equal to the quantity of irrigation water applied. This is based on application of 70 inches of irrigation water plus 31 inches of rainfall for a total of 101 inches per year. Losses through evapotranspiration are estimated at 24 inches per year. After allowing for 4 inches of loss through deep percolation, a balance of 70 inches will be discharged through the reuse ponds.

5. The cropping system designed is expected to remove only a portion of the total phosphorous and nitrogen applied in the wastewater. However, phosphorous not utilized by crops is expected to accumulate indefinitely in the soil. However, nitrogen not removed by crops is expected to be largely converted to soluble nitrate which will leach through to groundwater. Based on a nitrogen content of 20 ppm in the wastewater, there is a contribution of 315 pounds of nitrogen to each acre of soil receiving 70 inches of wastewater per year. It is assumed that 85% of this is removed and 15% would be discharge with the drainage water. To achieve this degree of removal, denitrification must be about 30-50% and crop uptake of nitrogen must annually exceed 100-150 pounds per acre.

6. This evaluation considers only effects upon land designated as the actual sites. It does not consider displacement effects associated with getting the wastewater to the disposal sites. Neither does it consider the impact of sludge disposal sites.

7. The dominant design criteria was wastewater renovation as contrasted to optimizing crop production. This allows heavier applications of water

per acre and a subsequent reduction in the total land requirements.

DISPOSAL SITE CHARACTERISTICS

Area Designation

Dow Engineering, Inc. has identified four areas within Michigan as potential wastewater disposal sites. Criteria included wastewater volume, soil type, and population density.

The proposed areas are shown on Figure 1. Portions of Huron and Tuscola Counties are covered by the largest site. The remaining three sites are in the Southeast Michigan Water Resources Study area. The St. Clair site covers portions of St. Clair, Macomb, and Sanilac Counties. The Lenawee and Monroe sites are located in the respective counties.

The area in the sites, excluding land in river corridors, totals 934 square miles, or 597,530 acres. The distribution among sites and the relationship of each area to total land in farms in the affected counties is:

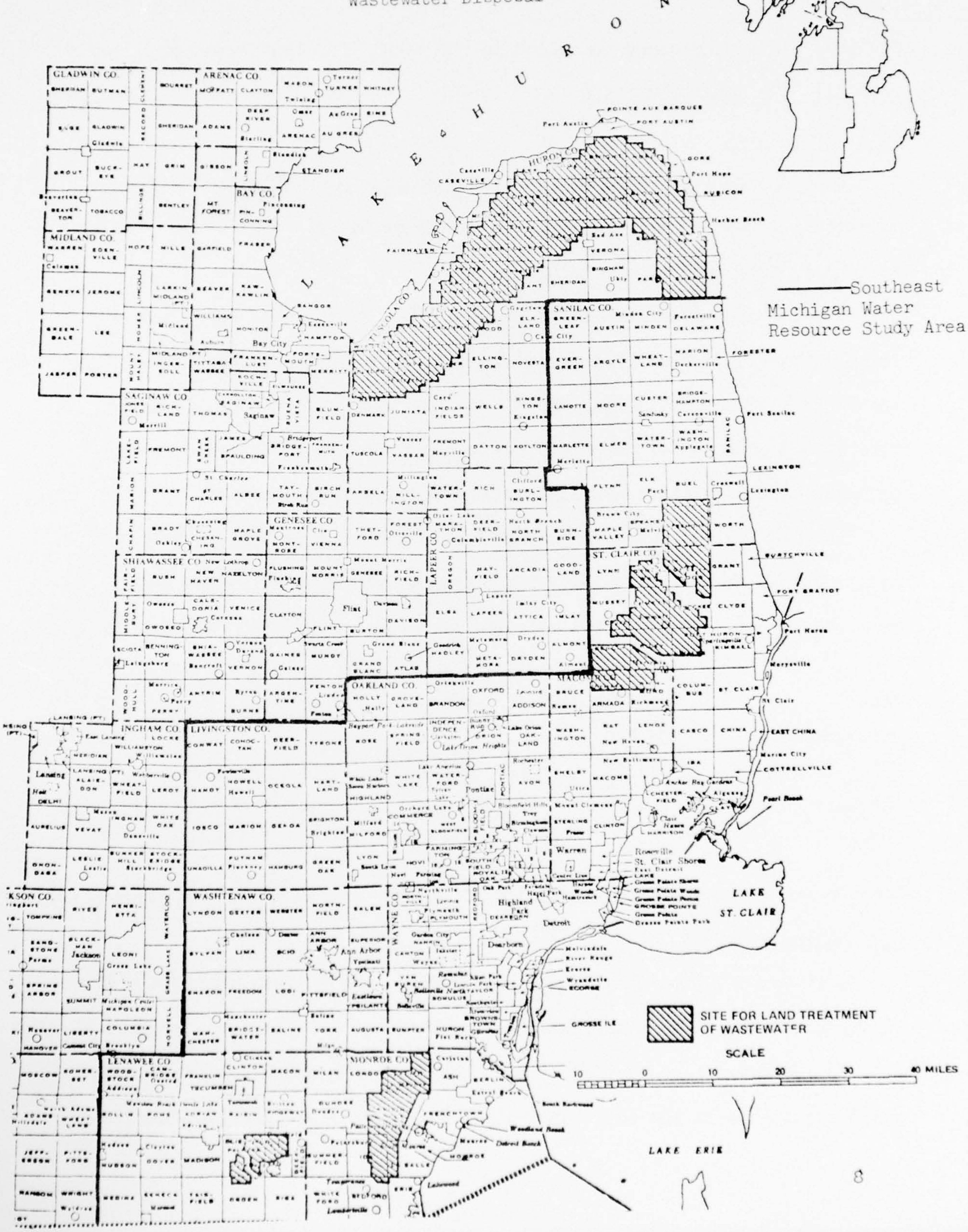
Site	Total Acres In Site	Percent of Total Cropland in County (1969)
Huron-Tuscola	388,970	49.5
St. Clair	149,220	19.2
Monroe	41,040	16.2
Lenawee	18,300	4.5
Total	597,530	

Data on the agricultural characteristics of the area is presented in Appendix 2.

Soil Resource Groups

Soil Conservation Service soil scientists, using soils maps and their knowledge of the area, classified the soils at each of the disposal sites into soil resource groups (SRG). Soil resource groups are land capability units aggregated on the basis of similar soil characteristics and use problems.

Figure 1: Designated Sites for Wastewater Disposal



In general, soils in a resource group have similar cropping patterns, yield characteristics and response to management problems. The acreage in the respective soil groupings is the basic building block for evaluating changes in cropping patterns and yields associated with wastewater disposal. All but SRG 7 are poorly drained in their natural state, presenting limitations for wastewater disposal (11). Extensive underdrain systems have been incorporated in the system design, but in some instances the rate of water application may have to be reduced below the design load of 70" per year. The share of total cropland in each SRG at the respective sites and a description of each group follows:

Site	Soil Resource Group	% of Total Cropland
Huron-Tuscola	16	61.2
	19	25.5
	7	6.8
	17	6.5
St. Clair	7	2.8
	16	41.0
	17	5.8
	18	15.0
	19	21.8
	20	9.0
	21	4.6
Monroe	16	80.0
	19	20.0
Lenawee	16	50.0
	17	50.0

SRG	Description
7	Well and moderately well drained, coarse and moderately coarse textured soils, some underlain by sand and gravel and some coarse textured soils underlain by bedrock at 20 to 40 inches. Permeability is rapid, available moisture capacity is low. Slopes are predominately 0-6 percent and erosion is slight to moderate.
16	Somewhat poorly and poorly drained, moderately fine and medium textured soils. Permeability is moderate to moderately slow and available moisture capacity is high to very high. Slopes are predominately 0-8 percent and erosion is slight.

SRG	Description
16 cont.	Some soils are underlain with gravel, sand or bedrock at a depth of 20 to 40 inches.
17	Somewhat poorly and poorly drained, moderately coarse textured soils. Permeability is moderate to moderately rapid and available water holding capacity is moderate. Erosion is slight to moderate and slopes are predominately 0-6 percent.
18	Somewhat poorly and poorly drained, moderately fine to fine textured surface soils and fine textured subsoils. They have slow permeability and high available moisture capacity. Slopes are predominately 0-6 percent.
19	Somewhat poorly, poorly and very poorly drained, moderately coarse and coarse textured soils. Some are underlain by sand and gravel and some are underlain by fine textured material at 20 to 40 inches. Some medium and moderately coarse textured soils with a fragipan are included. Permeability is moderate and available moisture capacity is medium to low. Slopes are predominately 0-6 percent and erosion is slight to moderate.
20	Somewhat poorly and poorly drained, moderately fine to moderately coarse textured (includes coarse texture in Michigan) alluvial and depressional soils frequently flooded. Permeability is moderate and available moisture capacity is medium. Slopes are predominately 0-6 percent and erosion is slight.
21	Very poorly drained organic soils (much and peats). Some soils included are underlain by mineral materials at depths of 20 to 40 inches.

Land Use and Production Changes

Production changes associated with wastewater disposal reflect 1) changes in the cropland base within the areas designated as disposal sites, and 2) changes in cropping patterns, yield response, and drainage on these acreages.

Estimates of land use at proposed sites, "with" and "without" disposal are in Table 2. Land use without disposal was estimated using allocators from Conservation Needs Inventory data. The land base for production estimates without disposal is the acreage in cropland and pasture. The area in spray modules at each site is the land base for estimates of

production with disposal. Acreage in the "support area" is used for lagoons, buffer strips, and other operational purposes. With wastewater disposal there is an increase in the acreage assumed in the production resource base. This is due to conversion of woodland and other land into cropland. For example, the production base at the Monroe site was estimated to be 40,960 acres with disposal and 35,100 acres without disposal. The total production base assumed for all four sites is 565,760 acres with disposal and 489,700 acres without disposal, an increase of approximately 16 percent.

Table 2: Assumed Land Use at Proposed Disposal Sites, With and Without Wastewater Application, 1980

Land Use	Lenawee	Monroe	St. Clair	Huron-Tuscola
	-----	-----	acres	-----
Without Disposal				
Cropland & Pasture	15,900	35,100	113,200	325,500
Forest & Woodland	1,900	3,400	24,900	46,800
Other Land	500	2,540	11,120	16,490
Total	18,300	41,040	149,220	388,790
With Disposal				
Module Area	15,360	40,960	138,240	371,200
Support Area	2,940	80	10,980	17,590
Total	18,300	41,040	149,220	388,790

The cropping pattern with disposal is quite different from that estimated without disposal. Permanent pasture is assumed to be converted into cropland. Land projected to be idled because of insufficient drainage will be cropped because of the designed underdrain system. There is a shift from grain crops to roughage crops because of wastewater application.

Silage and hay will replace small grains, corn for grain, and soybeans. In the Huron-Tuscola sites, substantial acreage of dry beans will be replaced by roughages.

Production will be affected by changes in crop yields associated with the quantity, quality, and timing of wastewater application. The existing basin studies provide estimates of 1980 yields without wastewater application. Very little data on the effect of wastewater application on crop yields in Michigan is available. Because of this, arbitrary adjustments were made to the yields expected by 1980 without wastewater application. These adjustments are intended to provide a range of yields reflecting negative and positive effects of wastewater application. The adjustments made were 10 and 25 percent decreases and 10 and 25 percent increases to the yields expected without disposal. The 10 - 25 percent yield increases with wastewater application may be conservative. Five year studies of wastewater application at Pennsylvania State University show greater yield increases associated with wastewater application. Yields from fields receiving 2" per week, compared with fields receiving 0" per week, increased 55 percent for corn for grain, 40 percent for corn for silage, and 118 percent for alfalfa (2).

Alternative Frameworks for Projections

Range rather than point estimates of crop production were developed because of the uncertainties surrounding the physical effects of wastewater application on crops and soils. While the amount of land and the application rates were held constant, production was estimated under several assumed cropping patterns and yields. The associated alternative production levels were

then translated into variables assumed to be a measure of impact, i.e. value of production, agricultural employment and population.

The following six frameworks reflect variations in yield and cropping patterns at proposed disposal sites. The first is a situation without disposal. The remaining five assume alternative effects of wastewater application on yields and cropping patterns. The rotation assumed with disposal is that in the Dow design, a ten year rotation consisting of two years of alfalfa-bromegrass, two years of corn for silage, two more years of alfalfa-bromegrass, and 3 years of reed canary grass is used. Estimates were made for an alternative rotation which substitutes corn for grain in place of corn for silage. The yields assumed under the alternative framework are summarized in Table 3.

Framework 1 (Benchmark) - This framework depicts the projected production from the designated areas without wastewater disposal. Projections from the Southeast Michigan and Great Lakes Basin study were disaggregated to the small site areas.

Framework 2 (Drainage Improvement) - This assumes changes in cropping pattern because of wastewater application, but no major yield change. The same yields as in Framework 1 were assumed, except that yields were estimated to increase on those soils that had drainage problems in the benchmark situation which were corrected by the construction of an underdrain system.

Framework 3 (25% Yield Decrease)- This provides the most pessimistic estimate of the yield effect of wastewater application. Benchmark yields were reduced 25%.

Framework 4 (10% Yield Decrease) - Benchmark yields were reduced 10%.

Framework 5 (10% Yield Increase) - Benchmark yields were increased 10 percent.

Framework 6 (25% Yield Increase) - This assumes the most optimistic yield effect of wastewater application, a 25% increase in yields.

Table 3: Assumed Yields Under Alternative Production Frameworks, Detroit Metropolitan Wastewater Management Study, 1980.

Crop	Unit	SRG	Framework 1/ 1,2	3	4	5	6
Corn	bu/ac	7	70	52	63	77	87
		16	118	88	105	129	147
		17	101	76	91	111	127
		18	108	81	97	118	134
		19	84	63	75	92	105
		20	100	75	90	110	125
		21	115	86	104	126	144
Corn Silage	ton/ac	7	12.5	9.4	11.3	13.4	15.6
		16	19.4	14.6	17.5	21.3	24.3
		17	17.2	12.9	15.5	18.9	21.5
		18	18.9	14.2	17.0	20.8	23.6
		19	16.4	12.3	14.8	18.0	20.5
		20	18.9	14.2	18.0	20.8	23.6
		21	19.8	14.9	17.8	21.8	24.8
Alfalfa hay	ton/ac	7	2.4	1.8	2.2	2.6	3.0
		16	2.9	2.2	3.2	4.0	3.6
		17	2.9	2.2	2.6	3.2	3.6
		18	3.1	2.3	2.8	3.4	3.9
		19	2.9	2.2	2.6	3.2	3.6
		20	3.1	2.3	2.8	3.4	3.9
		21	2.8	2.1	2.5	3.1	3.5
Reed Canary Grass Hay	ton/ac	7	2.8	2.1	2.5	3.1	3.5
		16	4.1	3.1	3.7	4.5	5.1
		17	3.3	2.5	3.0	3.6	4.1
		18	3.6	2.7	3.2	4.0	4.5
		19	3.3	2.5	3.0	3.6	4.1
		20	3.6	2.7	3.2	4.0	4.5
		21	3.2	2.4	2.9	3.5	4.0

1/ Framework 1 and 2 - 1980 Benchmark Yields. Changes from benchmark yields are:
Framework 3 -- 25% decrease
Framework 4 -- 10% decrease
Framework 5 -- 10% increase
Framework 6 -- 25% increase

Estimates of Cropping Patterns and Production

Projections "with" and "without" wastewater application indicate major changes in cropping patterns and production. Estimates of land use patterns appear in Table 4. There is a considerable shift in land use assumed with wastewater application. For all four sites approximately 231,300 acres (38.7% of the total area) is assumed to shift from idle, forest and woodland and other use to crop production with wastewater disposal, after taking into consideration acreage required for module support areas. Acreage in corn, alfalfa, and reed canary grass increases substantially, while zero acreage is assumed in other crops. Of particular significance at the Huron-Tuscola site is the displacement of a specialty crop, dry edible beans due to low tolerance to heavy water application. It is estimated that 51,900 acres of dry beans would be displaced by wastewater application.

Estimates of production with and without wastewater disposal indicate substantial increases in the crops in the design rotation, even under the most pessimistic assumption of yield effect (Table 5). This is due largely to the increased acreage in the particular crops grown. Production of corn silage from the four sites is estimated to increase 9 to 14 times with disposal. Alfalfa production is estimated to increase by 12 to 20 times. If corn for grain is assumed in the rotation instead of corn silage, the production increase would be less, but would still increase by a factor of 2 to 3.5.

The average yields implicit in the projections of acreage and production are in Table 6. These represent a weighted average of the soil resource groups at all sites.

Table 4: Cropping Patterns Based on Alternative Production Assumptions, Proposed Wastewater Disposal Sites, 1980.

Site	Crop	Framework[1/] 1	Framework[1/] 2-6	Site	Framework[1/] 1	Framework[1/] 2-6
		Acres				
St. Clair				Monroe		
	Wheat	10,725	0		5,002	0
	Oats	6,435	0		276	0
	Corn-grain	6,690	(27,648)[2/]		5,076	(8,192)[2/]
	Corn-silage	2,518	27,648		379	8,192
	Soybeans	929	0		18,081	0
	Alfalfa	6,628	69,120		212	20,480
	Other Hay	9,487	0		22	0
	Pasture	9,932	0		448	0
	Specialty Crops[3/]	12,540	0		592	0
	Idle	47,316	0		5,101	0
	Reed Canary Grass	0	41,472			12,710
	Forest & Woodland	24,900	0		3,400	0
	Other	11,120	0		2,540	0
	Support Area	0	10,980		0	80
	Total	149,220	149,220		41,040	41,040
Lenawee				Huron-Tuscola		
	Wheat	1,172	0		41,098	0
	Oats	406	0		5,132	0
	Corn-grain	1,681	(3,072)[2/]		29,648	(74,244)[2/]
	Corn-silage	86	3,072		8,072	74,244
	Soybeans	8,164	0		19,115	0
	Alfalfa	90	7,680		14,444	185,610
	Other Hay	10	0		5,786	0
	Pasture	223	0		30,027	0
	Specialty Crops[3/]	1,322	0		72,142	0
	Idle	2,746	0		100,036	0
	Reed Canary Grass		4,608			111,366
	Forest & Woodland	1,900	0		46,800	0
	Other	500	0		16,490	0
	Support Area	0	2,940		0	17,590
	Total	18,300	18,300		388,790	388,790

Table 4: Cropping Patterns Based on Alternative Production Assumptions, Proposed Wastewater Disposal Sites, 1980 (Cont'd).

Site	Crop	Framework 1/ 1	Framework 1/ 2-6	Site	Framework 1/ 1	Framework 1/ 2-6
		Acres				
Sum of				Four		
Lenawee,	Wheat	16,899	0	Site	57,997	0
Monroe &	Oats	7,117	0	Total	12,249	0
St. Clair	Corn grain	13,447	(38,912) 2/		43,095	(113,156) 2/
	Corn silage	2,894	38,912		10,966	113,156
	Soybeans	27,174	0		46,289	0
	Alfalfa	6,930	97,280		21,374	282,890
	Other hay	9,519	0		15,035	0
	Pasture	10,603	0		40,630	0
	Specialty Crops	14,454	0		86,596	0
	Idle	55,163	0		155,199	0
	Reed Canary Grass	0	58,250		0	169,616
	Forest & Woodland	30,200	0		77,000	0
	Other	14,160	0		30,650	0
	Support Area	0	14,000		0	31,590
	Total	208,560	208,560		597,350	597,350

1/ Alternative Frameworks:
1. Estimated acreage without wastewater application
2. Yields same as without application all acreage assumed well drained
3. 25% reduction in yields, all acreage assumed well drained
4. 10% reduction in yields, all acreage assumed well drained
5. 10% increase in yields, all acreage assumed well drained
6. 25% increase in yields, all acreage assumed well drained

2/ The assumed rotation in the design assumes corn silage rather than corn for grain. If grain rather than silage were assumed the bracketed data would replace the silage data.

3/ Specialty crops include dry edible beans, sugar beets, fruits, vegetables, and miscellaneous small grains. At the Huron-Tuscola site, 51,900 acres of dry beans are estimated to produce 830,600 c.w.t.

Table 5: Projected Agricultural Production From Proposed Wastewater Disposal Sites, 1980.

Site	Crop	Units	Framework[1] 1	2	3	4	5	6
St. Clair	Wheat	bu	468,601	0	0	0	0	0
	Oats	bu	415,021	0	0	0	0	0
	Corn-grain	bu	692,822	(2,894,591	2,170,943	2,605,133	3,184,050	3,618,239)[2]
	Corn-silage	tons	43,374	506,612	379,959	455,951	557,274	633,267
	Soybeans	bu	31,588	0	0	0	0	0
	Alfalfa hay	tons	18,166	222,316	166,739	200,084	244,548	277,895
	Other hay	tons[3]	18,714	0	0	0	0	0
	Pasture	tons[3]	9,167	0	0	0	0	0
	Reed Canary Grass	tons		152,676	114,507	137,408	167,945	190,846
Monroe	Wheat	bu	220,259	0	0	0	0	0
	Oats	bu	19,091	0	0	0	0	0
	Corn-grain	bu	450,474	(907,359	680,519	816,624	998,095	1,134,199)[2]
	Corn-silage	tons	4,282	154,011	115,508	138,610	169,412	192,514
	Soybeans	bu	602,147	0	0	0	0	0
	Alfalfa hay	tons	509	70,860	53,145	63,774	77,946	88,575
	Other hay	tons[3]	46	0	0	0	0	0
	Pasture	tons[3]	482	0	0	0	0	0
	Reed Canary Grass	tons		48,025	36,019	43,223	52,827	60,032
Lenawee	Wheat	bu	53,368	0	0	0	0	0
	Oats	bu	27,132	0	0	0	0	0
	Corn-grain	bu	149,016	(366,077	252,058	302,469	369,685	420,096)[2]
	Corn-silage	tons	1,304	56,217	42,163	50,955	61,839	70,271
	Soybeans	bu	278,028	0	0	0	0	0
	Alfalfa hay	tons	216	24,960	18,720	22,464	27,456	31,200
	Other hay	tons[3]	20	0	0	0	0	0
	Pasture	tons[3]	213	0	0	0	0	0
	Reed Canary Grass	tons		17,049	12,787	15,344	18,754	21,311

Table 5: Projected Agricultural Production From Proposed Wastewater Disposal Sites, 1980 (Cont'd).

Site	Crop	Units	Framework 1/					
			1	2	3	4	5	6
Huron-Tuscola	Wheat	bu	2,067,799	0	0	0	0	0
	Oats	bu	441,320	0	0	0	0	0
	Corn-grain	bu	2,806,391	(7,767,654	5,825,741	6,990,889	8,544,419	9,709,569) 2/
	Corn-silage	tons	124,849	1,338,083	1,003,563	1,204,275	1,471,892	1,672,604
	Soybeans	bu	517,983	0	0	0	0	0
	Alfalfa hay	tons	36,846	611,474	458,607	550,326	676,622	764,344
	Other hay	tons 3/	11,718	0	0	0	0	0
	Pasture	tons	45,581	0	0	0	0	0
	Reed Canary Grass	tons		418,246	318,685	376,422	460,070	522,807
Sum of St. Clair, Monroe and Lenawee	Wheat	bu	742,228	0	0	0	0	0
	Oats	bu	461,244	0	0	0	0	0
	Corn-grain	bu	1,292,312	(4,138,027	3,103,520	3,724,226	4,551,830	5,172,534) 2/
	Corn-silage	tons	48,960	716,840	537,631	645,156	788,524	896,052
	Soybeans	bu	911,763	0	0	0	0	0
	Alfalfa hay	tons	18,891	318,136	238,602	286,322	349,950	397,670
	Other hay	tons 3/	18,780	0	0	0	0	0
	Pasture	tons	9,862	0	0	0	0	0
	Reed Canary Grass	tons	0	217,750	163,313	195,975	239,525	272,189
Sum of four sites	Wheat	bu	2,810,027	0	0	0	0	0
	Oats	bu	902,564	0	0	0	0	0
	Corn-grain	bu	4,098,703	(11,905,681	8,929,261	10,715,115	13,096,249	14,882,103) 2/
	Corn-silage	tons	173,809	2,054,923	1,541,194	1,849,431	2,260,416	2,568,656
	Soybeans	bu	1,429,746	0	0	0	0	0
	Alfalfa hay	tons	55,737	929,610	697,211	836,648	1,022,572	1,162,014
	Other hay	tons 3/	30,498	0	0	0	0	0
	Pasture	tons	55,443	0	0	0	0	0
	Reed Canary Grass	tons		635,996	481,998	572,397	699,595	794,996

1/ Alternative Framework:
1. Estimated production without wastewater application
2. Yields same as without application, all acreage assumed well drained
3. 25% reduction in yields, all acreage assumed well drained
4. 10% reduction in yields, all acreage assumed well drained - 5. 10% increase in yields, all acreage assumed well draine
6. 25% increase in yields, all acreage assumed well drained

Table 6: Weighted Average Yield Implicit in Acreage and Production Projections for Wastewater Disposal Sites.

Crop	Unit	Site	Framework 1/ 1	2	3	4	5	6
			(Yield Per Acre)					
Corn for silage	tons	St. Clair	17.2	18.3	13.7	16.5	20.2	22.9
		Monroe	14.8	18.8	14.1	16.9	20.7	23.5
		Lenawee	15.2	18.3	13.7	16.4	20.1	22.9
		Huron-Tuscola	15.5	18.0	13.5	16.2	19.8	22.5
Corn for Grain	bu	St. Clair	103.6	104.7	78.5	94.2	115.2	130.9
		Monroe	88.7	110.8	83.1	99.7	121.8	138.5
		Lenawee	88.7	109.4	82.1	98.5	120.3	136.8
		Huron-Tuscola	94.7	104.6	78.5	94.2	115.1	130.8
Alfalfa	tons	St. Clair	2.7	3.2	2.4	2.9	3.5	4.0
		Monroe	2.4	3.5	2.6	3.1	3.8	4.3
		Lenawee	2.4	3.3	2.4	2.9	3.6	4.1
		Huron-Tuscola	2.6	3.3	2.5	3.0	3.6	4.1
Reed Canary Grass	tons	St. Clair	0	3.8	2.8	3.3	4.1	4.6
		Monroe	0	3.8	2.8	3.3	4.2	4.7
		Lenawee	0	3.7	2.8	3.3	4.1	4.6
		Huron-Tuscola	0	3.8	2.9	3.4	4.1	4.7

1/ Framework 1 assumes no wastewater application. Framework 2 represents the benchmark situation with disposal. Frameworks 3, 4, 5 and 6 represent yields of 75, 90, 110 and 125 percent respectively of the benchmark yields.

Estimates of Selected Indicators

Estimates of the value of production, agricultural employment, and population associated with alternative levels of production indicate increases with wastewater application (Tables 7 and 8). The difference between these tables is that Table 7 is based on a rotation assuming corn grown for silage, and Table 8 is based on a rotation assuming corn grown for grain.

All indicators increase directly with growth in production. However compared to the larger regional projections for Great Lakes Subareas 3.2 and 4.1, the absolute size of the indicators is small. For example, referring to

data in Table 7, the total value of production from the three sites in Planning Subarea 4.1 is only 8.7% of the estimated value of production for the entire subarea, under the most optimistic assumption.1/ The projected increase in value of production due to wastewater application for all four sites is between 11 percent (framework 3) and 84 percent (framework 6). Employment and population associated with agricultural production are both projected to increase between 49 and 148 percent.

Increases are also estimated for the rotation substituting corn for grain for corn silage. However, the magnitude of increase is less. The ranges of increases over the situation without wastewater application, as depicted in frameworks 3 and 6 are: 1) value of production; increases of from .6 of 1 percent to 67 percent, and 2) employment and population from 12 to 87 percent.

Agricultural production with wastewater application requires more labor because of labor intensive nature of the roughage crops in the design rotations, i.e. silage and hay. Labor requirements decrease when corn for grain replaces corn for silage in the rotation.

Population estimates are directly related to employment estimates. These individuals represent the family units of employees involved in agricultural operations. However, given that much of the work may be hired on a custom basis, these families may reside in towns in the area instead of on farms.

1/ ($18,258 ÷ $210,313)

Table 7: Alternative Levels of Value of Production, Agricultural Employment and Farm Population Associated With Alternative Production Frameworks, Corn for Silage Rotation, Southeast Michigan Wastewater Disposal Sites, 1980. 1/

Item	Site	Framework 2/ 1	2	3	4	5	6
Value of Production ($1,000)	St. Clair	5,696	10,258	7,694	9,233	11,284	12,823
	Monroe	2,407	3,203	2,403	2,883	3,524	4,004
	Lenawee	1,224	1,145	859	1,031	1,259	1,431
	Subtotal	9,327	14,606	10,956	13,147	16,067	18,258
	Huron-Tuscola	19,394	27,755	20,816	24,979	30,530	34,694
	Total	28,721	42,301	31,772	38.126	46,597	52,952
	G.Lakes PSA 4.1	210,313					
	G.Lakes PSA 3.2	266,567					
Agricultural Employment	St. Clair	301	654	491	589	720	818
	Monroe	66	205	153	184	225	256
	Lenawee	43	73	56	66	80	91
	Subtotal	401	932	700	839	1,025	1,165
	Huron-Tuscola	950	1,773	1,330	1,596	1,951	2,217
	Total	1,360	2,705	2,030	2,435	2,976	3,382
	G.Lakes PSA 4.1	8,065					
	G.Lakes PSA 3.2	16,600					
Population	St. Clair	1,084	2,354	1,768	2,120	2,592	2,945
	Monroe	237	738	551	662	810	922
	Lenawee	155	263	202	238	288	328
	Subtotal	1,476	3,352	2,521	3,020	3,690	4,195
	Huron-Tuscola	3,420	6,383	4,788	5,764	7,024	7,981
	Total	4,896	9,738	7,309	8,766	10,714	12,176
	G.Lakes PSA 4.1	29,033					
	G.Lakes PSA 3.2	59,700					

1/ Data based on production from rotation of corn for silage, alfalfa, and reed canary grass.

2/ Framework 1 assumes no wastewater application. Yields and rotation are 1980 benchmark levels. Frameworks 2-6 assume wastewater application and subsequent changes in rotations and crop yields. Yield changes, expressed in relationship to those in framework 1 are: Framework 2 - no change; Framework 3 - 25% decrease; Framework 4 - 10% decrease; Framework 5 - 10% increase; and Framework 6, 25% increase.

Table 8: Alternative Levels of Value of Production, Agricultural Employment and Farm Population Associated With Alternative Production Frameworks, Corn For Grain Rotation, Southeast Michigan Wastewater Disposal Sites, 1980. 1/

Item	Site	Framework 2/ 1	2	3	4	5	6
Value of Production ($1,000)	St. Clair	5,696	9,267	6,950	8,340	10,193	11,583
	Monroe	2,407	2,931	2,198	2,638	3,224	3,664
	Lenawee	1,224	1,051	788	946	1,156	1,314
	Subtotal	9,327	13,249	9,936	11,924	14,573	16,561
	Huron-Tuscola	19,394	25,265	18,949	22,738	27,791	31,581
	Total	28,721	38,514	28,885	34,662	42,364	48,142
	G.Lakes PSA 4.1	210,313					
	G.Lakes PSA 3.2	266,567					
Agricultural Employment	St. Clair	301	489	367	440	538	611
	Monroe	66	155	116	139	170	193
	Lenawee	43	55	41	50	61	69
	Subtotal	401	699	524	629	769	873
	Huron-Tuscola	950	1,339	1,004	1,205	1,473	1,673
	Total	1,360	2,038	1,528	1,834	2,242	2,546
	G.Lakes PSA 4.1	8,065					
	G.Lakes PSA 3.2	16,600					
Population	St. Clair	1,084	1,760	1,321	1,584	1,937	2,200
	Monroe	237	558	418	500	612	695
	Lenawee	155	195	148	180	220	248
	Subtotal	1,476	2,516	1,887	2,264	2,769	3,143
	Huron-Tuscola	3,420	4,821	3,615	4,338	5,303	6,023
	Total	4,896	7,337	5,502	6,602	8,072	9,166
	G.Lakes PSA 4.1	29,033					
	G.Lakes PSA 3.2	59,700					

1/ Data based on production from rotation of corn for grain, alfalfa, and reed canary grass.

2/ Framework 1 assumes no wastewater application. Yields and rotation are 1980 benchmark levels. Frameworks 2-6 assume wastewater application and subsequent changes in rotations and crop yields. Yield changes, express in relationship to those in Framework 1 are: Framework 2 - no change; Framework 3 - 25% decrease; Framework 4 - 10% decrease; Framework 5 - 10% increase; and Framework 6, 25% increase.

FARM ORGANIZATION

Resource Considerations

The ultimate form of any land disposal operation will be influenced by the availability of resources; land, labor and capital. Some factors influencing resource use are presented below:

Land. The amount of land the disposal authority controls establishes bounds upon the cropping potentials. The Dow design assumes that water will be applied at a rate of 2" per week or 70" per year applied during the frost free period. Working from the projected volume of wastewater, the required amount of land can be determined. However, if control over the estimated 600,000 acres appears unlikely, disposal criteria may have to be revised.

Labor. It may be assumed that labor is not a fixed factor and that hiring of full-time and seaonsal workers can be readily accomplished. However experience at the Muskegon, Michigan disposal site indicates some difficulties may be encountered in obtaining sufficient labor.

Capital. The capital requirements of acquisition and installation are very great. Land acquisition and family relocation for the four Michigan sites has been estimated at approximately 500 million dollars. Annual costs for capital, operation and maintenance, and project administration and labor are estimated at 156 million dollars.

Whether resources are owned or controlled will be function of the strength of the authority organized to operate disposal sites. If a regional authority were created, its financial power would influence whether land would be purchased outright or if some form of lease agreements would be arranged with present land owners. Arrangements for working capital for operation of irrigation modules and farming operations are necessary.

Perhaps the most overriding constraint on the organization of the disposal farms will be the exogenous decision made concerning the relative position of the farming operation within the overall objective of wastewater disposal and nutrient removal. Alternative assumptions can be made here.

1. Net returns from agricultural operations are a "bonus" to the total costs of the disposal program. Under this assumption, the prime objective will be water renovation. Farm operating costs would be included in the total cost of the disposal system.

2. Net returns from the farming operations would cover the entire operating costs of disposal from the point of arrival at the disposal zone.

3. The assumption made by Down, Inc. was that the cost of producing crops are equivalent to the revenue received from farm products.

Comparative Advantage

Individual farms usually are organized on the basis of customs and trial and error operating within the framework of market forces. Typical cropping patterns emerge in regions in response to the relative advantage that the region enjoys vis-a-vis other regions. Thus, the existing farm organization in the areas proposed for wastewater disposal is assumed to reflect the existing comparative advantage of the regions. The introduction of wastewater disposal on substantial acreage will modify these relationships.

For example, census data indicate that the counties where sites are proposed are oriented to the production of row crops (corn for grain, soybeans, and dry beans) rather than toward roughages (corn silage and hays). Huron and Tuscola Counties represent an even clearer example of the types of possible changes inherent in shifting to disposal type operations. Between 34 and 37 percent of the harvested cropland on class 1-5 farms[1/] was in dry

1/ Class 1-5 farms include all farms with sales of $2,500 and over.

beans in 1969. The percentage in corn silage and hays was 21 percent in Huron and 11 percent in Tuscola County.

Organizational Implications

The organization of agricultural production at wastewater sites will be evolutionary in nature. Organization patterns for large scale operation, such as those in the western United States provide some guidelines. However, even these fall short of being adequate models for study.

Whatever organizational form is used, certain economies of size may be experienced which could lower the per unit costs of production on disposal site acreages relative to both the surrounding farms in the region and other regions of the country.

There are numerous studies of the agricultural economies of size in agriculture. A common conclusion has been that family sized operations of one to three men exhaust most of the possible economies of size in midwest corn production. These conclusions have been criticized for failing to note the possibilities of starting operations on a large scale instead of increasing gradually. Krause and Kyle have hypothesized that economies of size at a much larger scale are possible and can be achieved by spreading some internal fixed costs over more units of output and by reducing input costs by volume purchasing (1). Their results showed input discounts over twenty percent for a 5,000 acre unit. Compared with a 500 acre unit discounts provided an incentive of approximately $13 an acre for corn production. Direct selling to a terminal market provided an additional economy of $5 net returns per acre for the 5,000 acre unit. The input discounts and marketing advantages of this larger operation more than offset the higher management, labor and operating credit costs that the 5,000 acre unit incurred compared with the 500 acre unit.

The first waste disposal farms would likely begin as large scale operations rather than gradual growth projects. If economies of size of the magnitude indicated above were to be achieved, surrounding smaller units could be placed at a competitive disadvantage. Since public funds and policy may be a factor in the establishments of sites, careful consideration needs to be given to this possibility.

Operational Considerations

Frequent rainfall throughout the growing season often hinders timely seeding, cultivation and harvesting of crops in Michigan. The addition of an average application of 2 inches of wastewater per week will compound this problem and require skillful management and coordination. Capacity exists to store wastewater when weather or operational considerations make application impractical. The Dow design has an excess storage capacity of 35 days. That is, it assumes application 35 weeks of the year (245 days) and a capacity in the storage lagoons to handle a 155 day accumulation of wastewater. Based on a 365 day year, there are 35 additional days that wastewater could accumulate while the irrigation system is inoperative. There is also a capacity in holding ponds to accumulate one week's drainage of treated wastewater prior to its discharge into streams.

Another potential problem is insufficient equipment. If hiring on a custom basis is expected to accomplish most of the cropping operations, assuring availability of sufficient equipment at the right time could be a problem. Some operational capacity, rather than complete reliance on custom operators might have to be created.

One of the biggest issues to be faced is the use of all the roughage produced on the disposal sites. Shipping costs for such bulky commodities suggest the need for their utilization near the point of production. This

implies a large increase in livestock operations near disposal sites or creation of a pelletizing industry. This would cause some major realignments in the structure of agricultural production, particularly in Monroe and Tuscola Counties which are oriented heavily to cash crop rather than livestock production (See Appendix Table 7).

A complete analysis of the relationship of livestock and disposal operations is needed, but is beyond the scope of this report. Some critical questions would seem to be: 1) What type of livestock operations are compatible with wastewater operations; dairy? cow-calf? feeder cattle?; 2) Where will livestock of the desired type come from?; 3) What can be the expected annual production of livestock?; 4) Where will additional livestock be marketed and what existing sources of supply are likely to be displaced?; 5) How will additional animal wastes be disposed?

Additional Implications

The initiation of wastewater disposal operations at the proposed sites could disrupt the existing channels through which machinery, petroleum products, seed, and fertilizer are distributed. The number of local suppliers could be reduced through emphasis on volume purchases. Conceivably, local suppliers could be bypassed completely if minimizing the unit cost of inputs became the dominant criterion. The need for commercial fertilizer may be reduced or eliminated due to substitution of nutrients in wastewater for purchased nutrients. The potential loss in fertilizer sales, if there was a complete substitution, would vary from .17-.19 ton or $14-$17 of sales per harvested acre, based on 1969 census data.

Changes in cropping patterns at the disposal sites has land use implications for the surrounding subareas. The rotation assumed is roughage oriented.

Production of corn silage, alfalfa, and reed canary grass will increase. If regional requirements for commodities displaced by wastewater disposal are to be produced, production will increase at other locations within the regions. The regional supply of the roughage will increase substantially, and, as mentioned previously, necessitate a closer look at its utilization.

SUMMARY AND CONCLUSIONS

The focus of this report has been to identify possible impacts on the agricultural economy in 1980 associated with the proposed land disposal of municipal wastes from the Detroit Metropolitan area. A comparison was made between projections for the proposed sites "with" and "without" disposal. Due to the lack of knowledge of effects of disposal on crop yields, a range of yields was assumed for corn for grain, corn silage, alfalfa, and reed canary grass. Production of these crops on the approximately 600,000 acres in the proposed sites were estimated for the different yield assumptions, and compared to estimates of production "without" disposal. Production estimates were converted to estimates of value of production, employment and population.

Significant increases in roughage production are projected with wastewater disposal. Referring back to Table 5, alfalfa hay "with" disposal is estimated to be 12-21 times greater than "without." Corn silage production is estimated to increase 9-15 times, depending upon the framework assumed. Large amounts of reed canary grass are estimated to exist where previously there was none. Production of crops other than corn, alfalfa, and reed canary grass was assumed to displace all other crops on the disposal sites. A significant impact in the Huron-Tuscola site is the displacement of approximately 52,000 acres of dry edible beans.

Indicators associated with agricultural production (value of output, employment, and population) increased with wastewater application, relative to projections without disposal. However compared to the larger regional projections for subareas containing the sites, the absolute size of these indicators is small. Employment increases reflect the labor intensive nature of roughage production. Labor requirements may be overstated, as no adjustment was made in the assumed labor requirements per unit of output to reflect larger scale planting and harvesting methods likely to be used at the disposal sites. It should be noted again that "with" disposal, acreage in the proposed sites was assumed to be cleared of the small acreage of woodland existing in the "without" situation. No effort was made to evaluate possible impacts on timber production and related income and employment. Production "with" disposal assumes that all acreage projected to be idled in the "without" projections because of government programs or other reasons is brought into crop production.

Increases in production with disposal reflect changes in yields as well as changes in the land area on which crops were grown. An alternative comparison might have been made between production "with" and "without" disposal on an identical acreage base. However, the intent of this paper has been to identify a range of the magnitudes of the total change in the region rather than the components of change on a particular area of land.

A wastewater disposal project of the magnitude proposed for the Detroit metropolitan area is expected to have a significant impact on the agricultural economy of the immediate disposal sites, with a lesser impact on the surrounding region. Additional study is needed to refine impacts and to assign magnitudes

as well as direction to more probable changes. For example, disposal of the increased roughage production is one area needing further study. If the livestock industries is to be increased many issues need to be resolved, as noted previously.

Further work related to the impacts on the total production of selected crops would be fruitful. The displacement of large acreages of dry beans, as well as other crops has implications for regional production.

Alternative methods of acquiring control of land for disposal need further study. Tradeoffs between buying sites versus renting or other methods of control need to be identified. As public money is likely to be involved, equity issues related to possible displacement effects need further study.

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APPENDICES

Appendix 1
Alternative Land Requirements

Land required for rennovation varies according to assumptions made with respect to the calculation of the total wastewater volume, the portion treated through land disposal, and the application rates. Variations in total volume due to alternative assumptions in per capita use rates are shown in Appendix Table 1. Industrial and stormwater volumes are held constant.

Different assumptions with respect to application rates of any given volume influence the land requirements considerably. Appendix Table 2 estimates land requirements for disignated volumes over one range of .5 to 3 inches per week for 35 weeks. These estimates are for disposal sites only and do not include land for storage, operation, and buffer zones.

Based on the assumptions one makes, the appendix tables can be used to estimate disposal acreage. For example, the 1980 Corps municipal discharge volume of 515.2 MGD (Table 1) plus municipal and stormwater discharge, totals 2,339,179 acre ft./year. Starting with this value in Appendix Table 2, land requirements ranging from 1604 to 267 thousand acres are indicated, depending upon the application rate selected.

Appendix Table 1 - Alternative Levels of Wastewater Volume, Detroit Metropolitan Area, 1970-2000.

Year	Population	Daily per Capita Use	Municipal Discharge (MGD)	Industrial MGD	M & I (acre ft./yr.)	Stormwater (acre ft./yr.)	Total (acre ft./yr.)
1970	4,687,200	(1)	426.9	1216.7	1,841,016	696,535	2,537,551
		80	375.0	1216.7	1,782,882	696,535	2,479,417
		100	468.7	1216.7	1,887,837	696,585	2,584,372
		140	656.2	1216.7	2,097,858	696,535	2,794,393
1980	5,362,800	(1)	515.2	951.3	1,642,644	696,535	2,339,179
		80	429.0	951.3	1,546,091	696,535	2,242,626
		100	536.3	951.3	1,666,279	696,535	2,362,814
		140	750.8	951.3	1,906,543	696,535	2,603,078
1990	6,130,300	(1)	614.8	828.2	1,616,322	696,535	2,312,857
		80	490.4	828.2	1,476,980	696,535	2,173,515
		100	613.0	828.2	1,614,305	696,535	2,310,840
		140	858.2	828.2	1,888,957	696,535	2,585,492
2000	7,863,400	(1)	714.5	705.0	1,589,999	696,535	2,286,534
		80	629.1	705.0	1,494,341	696,535	2,190,876
		100	786.3	705.0	1,670,423	696,535	2,366,958
		140	1100.9	705.0	2,022,810	696,535	2,719,345

(1) Estimate made by Detroit District Corps of Engineers.

Appendix Table 2 - Acreage Requirements for Land Disposal of Alternative Volumes of Wastewater, Detroit Metropolitan Area.[1/] [2/]

Wastewater Volume (acre ft./year)	Application Rate/week/35 weeks 5"	1"	2"	3"
	(1,000 acres)			
500,000	342.9	171.5	85.7	57.1
1,000,000	685.9	342.9	171.4	114.3
1,476,980	1,013.0	506.5	253.2	168.8
1,494,341	1,024.9	512.9	256.2	170.8
1,546,091	1,060.4	530.2	265.1	176.7
1,589,999	1,090.5	545.3	272.6	181.7
1,616,322	1,108.6	554.3	277.1	184.7
1,642,644	1,126.6	563.3	281.6	187.7
1,782,882	1,222.8	611.4	305.7	203.8
1,841,016	1,262.7	631.3	315.6	210.4
1,888,957	1,295.6	647.8	323.8	215.9
1,906,543	1,307.6	653.8	326.9	217.9
2,022,810	1,387.4	693.7	346.8	231.2
2,097,858	1,438.9	719.4	359.7	239.8
2,173,515	1,490.8	745.4	372.6	248.4
2,190,876	1,502.7	751.3	375.6	250.4
2,242,626	1,538.2	769.1	384.5	256.3
2,286,534	1,568.3	784.1	392.0	261.3
2,312,857	1,586.3	793.2	396.5	264.3
2,339,179	1,604.4	802.2	401.0	267.3
2,479,417	1,700.6	850.3	425.1	283.4
2,537,551	1,740.4	870.2	435.0	290.0
2,585,492	1,773.3	886.7	443.3	295.5
2,603,078	1,785.4	892.7	446.3	297.5
2,719,345	1,865.1	932.6	466.2	310.8
2,794,393	1,916.6	958.3	479.1	319.4

1/ This acreage is for disposal only, and does not include area for lagoons, buffer areas, etc.

2/ Conversion factors used:

Application Rate	Acre inches per year	Acre feet per year
1"/week, 35 weeks	35.0	2.916

Appendix 2
Agricultural Description

AREA DESCRIPTION

The sites identified for wastewater disposal lie within counties having varied agricultural characteristics. The following data provides a perspective on some of the salient agricultural data, as identified in the 1969 Census of Agriculture. Information is provided for the state and on a county basis for counties within the S.E. Michigan Water Resources Study area, plus Huron and Tuscola Counties.

Numbers, Value, and Size

Of the counties where sites are proposed, the larger farms are in Huron and Tuscola Counties, which also have the largest number and the greatest area in farms. Lenawee and Monroe County farms have the greatest total value.

Table A-1 : Farm Numbers, Size, and Value, 1969

County	Number of Farms	Average Size	Average Value per Farm	Average Value per Acre
		(acres)	------- (dollars) ---	
Huron	2,507	170	52,663	310
Lenawee	2,558	158	70,620	446
Livingston	1,099	158	75,246	475
Macomb	997	97	86,085	886
Monroe	2,000	127	72,310	570
Oakland	863	118	115,197	977
St. Clair	1,662	131	50,745	387
Sanilac	2,787	165	44,031	266
Tuscola	2,208	163	68,271	420
Washtenaw	1,699	153	76,658	501
Wayne	597	83	112,235	1,356
Subtotal	18,977	148	67,415	456
Michigan Total	77,946	153	49,821	326

Source: 1969 Census of Agriculture

Land Use

Huron and Tuscola Counties have the greatest area of harvested cropland followed closely by Lenawee County. Woodland and pasture cover roughly the same amount of area in those three counties.

Table A-2 : Land in Farms by Major Land Use, All Farms, 1969

County	Acres in Farms	Total Cropland	Harvested Cropland	Cropland used for Pasture	Woodland and Pasture	Other Land
	(1,000 Acres)					
Huron	426.2	361.2	273.8	27.4	33.3	31.8
Lenawee	403.6	335.3	241.0	12.3	30.9	37.4
Livingston	174.0	119.8	71.8	16.5	21.1	33.1
Macomb	96.9	77.4	47.3	6.9	23.1	10.5
Monroe	253.9	221.4	162.6	4.0	15.3	17.2
Oakland	101.8	68.1	33.4	14.2	13.7	20.0
St. Clair	218.2	174.4	97.4	26.8	21.3	22.6
Sanilac	461.1	389.1	263.2	50.2	34.1	37.9
Tuscola	359.1	298.8	238.7	18.8	30.9	29.4
Washtenaw	260.3	196.8	126.0	24.1	26.1	37.3
Wayne	49.5	38.9	25.6	2.4	4.6	6.1
Subtotal	2,804.8	2,281.2	1,580.8	203.5	254.4	283.4
Michigan Total	11,900.7	8,580.4	5,501.7	1,090.9	1,843.6	1,476.7

Source: 1969 Census of Agriculture

Land Use -Class 1-5 Farms

Class 1-5 farms utilize 82% of the total land in farms in the 11 county area and 84% of the total land in farms of the five counties in the area of the proposed sites. For this reason, and in order to widen the perspective of the study, tables on land in farms, harvested acreage in crops, farm income and sales and use of agricultural chemicals for Class 1-5 farms are included.

Table A-3 : Land in Farms, All Farms and Class 1-5 Farms, 1969

County	LAND IN FARMS All Farms	Class 1-5	Percent	Harvested Cropland Class 1-5
	(acres)			
Huron	426,244	376,787	88.39	257,884
Lenawee	403,602	349,366	86.56	222,247
Livingston	174,047	128,523	73.84	67,762
Macomb	96,934	72,478	74.77	41,074
Monroe	253,927	210,487	82.89	144,397
Oakland	101,820	72,547	71.25	27,977
St.Clair	218,207	150,126	68.79	79,966
Sanilac	461,108	381,942	82.83	239,245
Tuscola	359,139	304,875	84.89	223,427
Washtenaw	260,283	207,514	79.72	113,387
Wayne	49,527	35,788	72.25	20,728
Subtotal	2,804,838	2,290,433	81.66	1,433,094
Michigan Total	11,900,689	9,142,760	76.82	4,839,384

Source: 1969 Census of Agriculture

Crop Acreage

The distribution of the cropping pattern on harvested cropland on class 1-5 farms is an indicator of the relative importance of crops in a county. This relationship is representative of class 1-5 farms, which cover 81.66% of all the cropland in the region. Table A-4 indicates the relative importance of the crops in the counties.

The predominant crop grown in Huron and Tuscola Counties was dry field and seed beans. In 1969 it accounted for 34% of Huron County's harvested cropland acreage and 38% of Tuscola County's harvested cropland acreage. The primary crop grown in Lenawee and St. Clair Counties was corn for grain. Corn for grain accounted for 33% of the total harvested cropland in Lenawee County and 20% of the harvested cropland in St. Clair County. Forty-two percent of the harvested cropland in Monroe County was used to grow soybeans.

Table A-4: Distribution of Harvested Cropland on Class 1-5 Farms, 1969.

Crop \ County	Huron	Lena-wee	Living-ston	Macomb	Monroe	Oak-land	St. Clair	Sani-lac	Tus-cola	Wash-tenaw	Wayne	Sub-total	Mich. Total
	Percent												
Corn for Grain	16.72	33.05	28.50	22.63	25.25	25.76	19.63	16.72	14.80	30.77	17.74	21.96	22.66
Corn for Silage	7.26	5.50	12.07	8.94	2.28	5.89	11.98	10.84	2,89	6.19	2.06	6.74	6.41
Alfalfa Hay	10.23	6.15	27.08	16.25	2.58	32.70	16.75	18.10	7.54	19.84	5.75	12.13	16.13
Sugar Beets	5.08	.94			2.22		1.95	2.69	7.86			3.07	1.84
Dry field beans	34.23		.12	2.17			6.74	15.30	37.89			15.06	11.49
Other hays	3.08	1.37	4.02	4.49	.86	3.57	10.64	5.66	.95	4.62	2.87	3.32	4.12
Wheat	11.00	12.51	8.29	8.27	13.45	10.94	9.47	8.25	12.56	11.61	8.25	10.99	9.08
Oats	7.42	5.95	6.90	7.48	5.31	7.83	7.08	12.42	7.12	10.87	3.27	7.97	7.93
Barley	.43	.05	.07		.03	.06	.32	.25	2.62	.20		.58	.40
Rye	.12	.18	.65	.61	.32	.42	.30	.25	.58	.17	.03	.30	.52
Soybeans	1.05	31.93	1.07	6.19	41.87	1.15	4.56	1.33	1.37	8.77	43.22	11.63	8.14
Irish Potatoes	.06	.12	.03	1.14	1.84	.32	.08	0.0	.63	.29	.02	.38	.88
Other	3.32	2.25	11.20	21.83	3.99	11.36	10.50	8.19	3.19	6.47	16.79	5.87	10.40
Total	100.00	100.00	100.00	100.00	100.00	1.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: 1969 Census of Agriculture

Livestock Inventory

Livestock numbers are provided in table A-5. Huron County leads in numbers of cattle and calves, followed by Sanilac, Lenawee, and St. Clair. Huron also leads in numbers of milk cows.

Table A-5 : Numbers of Livestock, All Farms, 1969

County	Cattle & Calves	Milk Cows	Hogs & Saws	Sheep & Lambs	Chickens
Huron	68,594	18,081	12,916	673	783,556
Lenawee	46,691	8,771	38,036	12,765	284,342
Livingston	27,660	9,508	5,812	7,497	10,550
Macomb	12,574	4,966	2,649	1,683	62,489
Monroe	13,984	2,190	15,408	4,441	106,870
Oakland	12,008	2,820	3,009	2,584	58,162
St. Clair	34,506	10,057	3,547	2,350	167,282
Sanilac	77,314	31,995	7,697	1,421	41,358
Tuscola	28,336	9,616	9,207	2,420	342,495
Washtenaw	33,588	10,550	23,890	53,361	126,700
Wayne	2,328	537	1,584	500	32,362
Subtotal	357,583	109,091	123,755	89,695	2,016,166
Michigan Total	1,441,556	413,907	699,478	271, 24	7,311,189

Source: 1969 Census of Agriculture

Existing Irrigation

Relatively small areas of land are currently irrigated in the proposed site areas. A 1970 survey by the Michigan Water Resources Commission provided a complete inventory of irrigation in the counties (Table A-6).

Table A-6 : Number of Irrigators, Acreage Irrigated, and Water Use, 1970

COUNTY	NUMBER OF IRRIGATORS	ACRES OF LAND IRRIG.	AVERAGE ACRE INCHES OF WATER USE/YEAR
Huron	8	149	8.8
Lapeer	41	2,574	5.5
Lenawee	27	523	13.6
Livingston	36	1,264	9.8
Macomb	8	2,657	8.4
Monroe	27	1,476	6.7
Oakland	90	3,042	12.3
Sanilac	9	1,187	5.8
St. Clair	16	1,164	8.1
Tuscola	9	225	10.7
Washtenaw	51	1,391	20.6
Wayne	45	1,821	10.3
Total	444	17,473	

Source: (12)

Origin of Farm Income and Sales

Crop and livestock sales are the primary source of cash flow into agricultural operations. However, as noted in Table A-7, farm related income contributed between 4 and 10 percent of the total cash flow of class 1-5 farms in 1969.

For the class 1-5 farms in Huron, Lenawee and St. Clair Counties, livestock accounted for the greater proportion of farm income and sales. Crops, including nursery and hay, accounted for the greater proportion of farm income and sales in Monroe and Tuscola Counties.

Farm Related Income

Eighty-eight percent of farm related income for the five counties with proposed sites came from government farm programs. Less than one percent of the farm related income came from recreational services. Custom work and other agricultural services accounted for eleven percent of the farm related income. Lenawee County received the most farm related income ($3.87 million).

As noted in Table A-8 approximately 2/3 of all farms in the eleven county area had some kind of farm related income in 1969. Government payments were the most frequent as well as the largest source of dollars. The counties proposed land disposal sites all received sizable government payments in 1969. Income from custome work and other agricultural services was greatest in Huron, Tuscola, Sanilac, and Monroe Counties.

Table A-7 : Sources of Farm Income and Sales, Class 1-5 farms, Dollar Amount and Relative Share, 1969.

Item \ County	Huron	Lena-wee	Living-ston	Macomb	Monroe	Oak-land	St. Clair	Sani-lac	Tus-cola	Wash-tenaw	Wayne	Sub-total	Mich. Total
	($1,000)												
Crops	11,747	12,706	2,621	8.917	12,919	4,212	3,864	8,358	15,505	4,911	4,658	90,418	330,016
Nursery Forest Products	15	32	51	21	38	39	32	15	26	42	6	318	4,184
Livestock	22,424	18,258	8,127	4,135	6,035	4,281	11,701	23,641	10.004	12,863	889	122,362	462,296
Farm related Income	2,034	3,402	561	375	2,111	356	671	1,47[illegible]	2,146	1,311	27[illegible]	14,723	45,256
Total	35,220	34,399	11,360	13,448	21,103	8,888	16,268	33,48[illegible]	27,681	19,127	5,842	227,828	841,752
	(Percentage Distribution)												
Crops, Nursery and Hay	32.43	36.95	23.07	66.30	61.21	47.38	23.75	24.97	56.01	25.67	79.74	39.68	39.20
Forest Products	.04	.09	.45	.15	.18	.44	.17	.04	.09	.22	.09	.13	.49
Livestock	61.92	53.07	71.59	30.77	28.61	48.17	71.94	70.59	36.13	67.26	15.39	53.73	54.94
Farm related Income	5.61	9.89	4.94	2.78	10.00	4.01	4.12	4.40	7.77	6.85	4.78	6.46	5.37

Source: 1969 Census of Agriculture.

Table A-8: Source, Frequency and Amount of Farm Related Income, All Farms, 1969.

County \ Item	Custom Work and Other Services: No. of Farms	Custom Work and Other Services: Income	Recreational Services: No. of Farms	Recreational Services: Income	Farm Programs: No. of Farms	Farm Programs: Income	Total Farm Related Income	Percent of Total Income[1]	Participation Rate[2]
Huron	334	399,943	16	11,881	1,631	1,812,686	2,224,510	6.00	79.01
Lenawee	355	342,454	12	8,940	1,604	3,526,204	3,877,598	10.83	77.05
Livingston	80	128,852	23	17,802	524	603,917	750,571	6.26	57.05
Macomb	68	76,344	8	36,970	406	393,321	506,635	3.64	48.34
Monroe	236	219,412	13	38,855	1,162	2,226,664	2,484,931	11.02	70.55
Oakland	108	123,387	17	47,570	324	330,668	501,625	5.36	52.02
St. Clair	136	97,289	19	21,363	870	848,482	967,134	5.60	61.67
Sanilac	290	282,141	17	10,041	1,519	1,482,294	1,774,476	5.11	65.51
Tuscola	278	285,184	15	9,980	1,223	2,015,204	2,310,368	8.08	68.65
Washtenaw	175	241,717	27	40,138	934	1,304,476	1,586,331	7.92	66.86
Wayne	42	57,038	10	33,128	177	269,315	359,481	5.77	38.35
Subtotal	2,102	2,253,761	177	276,668	10,374	14,813,231	17,343,660	7.30	66.67
Michigan Total	8,134	9,268,310	760	1,184,542	38,467	45,660,085	56,112,937	6.33	60.76

Source: 1969 Census of Agriculture

1/ Total income equals value of farm products sold plus farm related income.

2/ Percentage of total number of farms receiving some form of farm related income.

Use of Agricultural Chemicals

As shown in Table A-9, commercial fertilizers were widely used in the area. Approximately 75% of the harvested cropland in class 1-5 farms received some fertilizer in 1969. Application rates clustered between .15 and .19 tons/acre, with the exception of Macomb County. Lime was applied less frequently but at heavier rates than fertilizer. Sprays, dusts and fumigants were used quite extensively, particularly in Huron, Lenawee, Tuscola, and Monroe Counties.

Table A-9: Agricultural Chemicals Used, Class 1-5 Farms, 196[illegible]

Item \ County	Huron	Lenawee	Livingston	Macomb	Monroe	Oakland	St. Clair
Commercial Fertilizer							
acres fertilized	208,185	164,142	38,265	30,056	115,126	16,179	53,298
% of harvested cropland	81	74	61	73	80	58	67
tons	34,580	31,664	6,574	6,804	22,232	2,668	9,960
dollars	2,989,561	2,754,689	529,904	548,998	1,822,663	219,272	787,270
tons/acres	.17	.19	.17	.23	.19	.16	.19
$/acres	14.36	16.78	13.85	18.27	15.83	13.55	14.77
Lime							
acres limed	1,093	7,604	1,940	1,119	2,213	451	535
tons	2,274	14,828	4,656	2,160	3,689	979	1,337
dollars	12,298	79,333	26,353	14,605	14,810	7,127	8,149
tons/acres	2.08	1.95	2.40	1.93	1.67	2.17	2.50
$/acres	11.25	10.43	13.58	13.05	6.69	15.80	15.23
Spray, dusts fumigants							
acres	133,174	137,761	28,843	21,323	86,777	11,246	32,300
dollars	701,790	587,700	134,676	227,604	520,789	96,882	190,306
Chemicals for defoilation							
acres	180	244	338	199	210	408	328
dollars	894	1,431	9,072	1,095	2,164	2,482	2,828
Insect control on livestock							
dollars	14,840	16,144	8,573	5,350	3,840	4,119	11,064
Total dollars	3,724,077	3,443,828	709,911	799,878	2,366,984	330,705	1,003,046

Table A-9 : (continued)

Item \ County	Sanilac	Tuscola	Washtenaw	Wayne	Subtotal	Michigan Total
Commercial Fertilized						
acres fertilized	170,917	190,108	75,529	14,797	1,076,602	3,449,288
% of harvested cropland	71	85	67	71	75	71
tons	29,493	33,073	11,675	2,585	191,308	595,179
dollars	2,481,434	2,764,312	1,013,713	227,903	16,139,719	49,671,380
tons/acres	.17	.17	.15	.17	.18	.17
$/acres	14.52	14.54	13.42	15.40	15.01	14.40
Lime						
acres limed	3,152	610	4,007	370	23,094	127,837
tons	7,780	1,375	8,700	525	48,303	290,258
dollars	42,582	6,930	43,044	3,231	258,462	1,605,797
tons/acres	2.47	2.25	2.17	1.42	2.09	2.27
$/acres	13.51	11.36	10.74	8.73	11.10	12.56
Spray, dusts fumigants						
acres	94,967	127,723	54,727	11,851	740,692	2,555,976
dollars	509,157	669,398	287,956	87,5 3	4,013,801	18,885,348
Chemicals for defoilation						
acres	204	1.031	310	62	3,514	34,790
dollars	1,263	6,681	2,222	129	30,281	287,135
Insect control on livestock						
dollars	22,101	8,954	13,043	748	108,776	432,132
Total Dollars	3,059,657	3,459,814	1,362,897	320,758	20,581,555	71,012,594

Source: 1969 Census of Agriculture

Detroit District
U.S. Army Corps of Engineers

final report

ECONOMIC ASSESSMENT SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT STUDY

CONTRACT NO. DACW 35-73-C-0042

MR. PAUL M. REID

Pleasant Ridge, Michigan

APRIL 1973

ECONOMIC ASSESSMENT OF SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT ALTERNATIVES

TABLE OF CONTENTS

TABLES

ECONOMIC ASSESSMENT

A. The Area Profile.

1. Overall Perspective.

The southeastern Michigan area is composed of nine counties, covering 6,240 square miles, with a 1970 population of 4,851,348 people. Seven river basins dominate the area: Black, Pine, Belle, Clinton, Rouge, Huron and Raisin Rivers. In the Great Lakes Basin studies, the southeastern Michigan region is designated as sub-basin 4.1 and forms a logical hydrologic entity.

The core economic activity of the area for some decades has been manufacturing, with automotive production the major component. From 1950 to 1970, total employment increased 471,933, from 1,343,172 to 1,815,105. Although manufacturing employment registered a small numerical increase, this sector of the economy declined from 45.8% to 36.8% of the total. During this period, non-manufacturing employment grew 415,223. The upsurge of employment in other than manufacturing has been a significant trend for at least 20 years in the Southeastern Michigan area, as well as in other major metropolitan areas. From 1954 to 1967, while manufacturing employment grew 64,108, employment in retail, wholesale and selected services mounted 131,430.

Urbanization has been spreading from the central city - Detroit - and from the other urban centers to the surrounding communities and townships. One feature of this movement has been the dispersed pattern of economic establishments, such as, manufacturing plants, shopping centers, office and professional service complexes. The largest portion of this spread of economic activity has been confined to the three central counties of Wayne, Oakland and Macomb, which make up the standard metropolitan statistical area. In 1950, employment in the Detroit Metropolitan Area constituted 88.8% of the total of the nine counties. By 1970 employment in these 3 counties still accounted for 82.3% of the regional total.

The population of the area is largely urban by settlement pattern and has become more so over the past two decades. From 1950 to 1970, population increase was 1,411,089 (from 3,440,259 to 4,851,348), but the urban percentage went up only a few points from 86.1 to 88.7. (<u>See</u> Table I.). The four central counties - Wayne, Oakland and Macomb of the Detroit standard

metropolitan statistical area and Washtenaw, which also constitutes its own metropolitan area, are predominately urban. The 1970 urban percentages of population were as follows: Wayne 98.2; Macomb 92.2; Oakland 90.0, and Washtenaw 78.2. The remaining five counties, on the other hand, were largely rural, ranging from zero to 46% urban.

Population densities parallel the urban settlement pattern. In 1970, the density rate for the entire area was 777.5 persons per square mile. Three counties had densities of over 1,000 - Wayne 4,421.6; Macomb 1,302.7 and Oakland 1,047.1. Sanilac had only 36.3 persons per square mile, while Lenawee and Livingston rated densities of a little over 100.

The center of population, as mirrored by the three central counties (Wayne, Oakland and Macomb), has been moving northwestward through Detroit since 1930. From 1930 to 1960, it jumped from the New Center District of Detroit (West Grand Boulevard and Second) to within a mile of the city's northern border on the west side. By 1970, it had crossed the Detroit border into the City of Southfield in Oakland County, in the area bounded by Nine and Ten Mile Roads, and Lahser and Telegraph Roads.[1]

Historically the region has had a high proportion of its population in the major age groups active in the labor force.

Since 1950, however, males and females in the 25 through 44 year age range have been declining as a portion of total population. In 1950, 31.1% of males and 33.1% of females were in the 25-44 year span. This ratio dropped to 27.4% of males and 28.3% of females in 1960. The 1970 Census figures show even further decline to 23.0% of males and 24.1% of females in this job age group.

2. Economic Development: 1950 to 1970.

During the 1950-1970 period, population and employment in the area increased at a greater rate than in the Great Lakes Basin as a whole. Total employment gained 471,933, with the larger increase (302,965) coming in the 1960-70 decade. The participation rate (employed workers per 100 persons in population) declined, falling from 39.04 in 1950 to 35.20 in 1960, then rising slightly to 37.41 in 1970. (*See* Table - II).

1 "Center of Population, Detroit Metropolitan Area, 1930-1960", Regional Planning Commission, April 1961.

Table - I

POPULATION TRENDS

Southeastern Michigan - Subarea 4.1

County	1950	1960	1970	1970 Density (Per Square Mile)
Lenawee	64,629	77,789	81,951	108.0
Urban	25,186	32,591	32,873	
%	37.1	41.8	40.3	
Livingston	26,725	38,233	58,967	103.1
Urban	4,353	4,861	6,493	
%	16.3	16.7	11.0	
Macomb	184,961	405,804	625,309	1,302.7
Urban	128,732	354,825	576,672	
%	69.6	87.4	92.2	
Monroe	75,666	101,120	118,479	212.7
Urban	22,162	27,993	41,424	
%	29.3	27.6	35.0	
Oakland	396,001	690,259	907,871	1,047.1
Urban	286,928	609,259	816,874	
%	72.5	88.2	90.0	
St. Clair	91,599	107,201	120,175	163.7
Urban	49,266	53,065	55,320	
%	53.8	49.5	46.0	
Sanilac	30,837	32,314	34,889	36.3
Urban	---	---	---	
%	0.0	0.0	0.0	
Washtenaw	134,606	172,440	234,103	329.2
Urban	86,698	121,484	182,994	
%	64.4	70.4	78.2	
Wayne	2,435,235	2,666,297	2,669,604	4,421.6
Urban	2,358,903	2,599,295	2,619,413	
	90.6	97.4	98.2	
Totals	3,440,259	4,291,457	4,851,348	777.5
Urban	2,962,228	3,803,373	4,332,063	
	86.1	88.6	88.7	

(Source: U.S. Census)

Table - II

TOTAL EMPLOYMENT

County	1950	1960	1970
Lenawee	23,554	26,284	30,064
Livingston	9,325	13,200	21,127
Macomb	63,360	133,915	228,429
Monroe	25,512	32,420	41,924
Oakland	146,981	240,861	344,320
St. Clair	32,600	35,039	41,207
Sanilac	10,727	10,930	11,699
Washtenaw	48,110	65,532	97,591
Wayne	983,003	953,959	998,204
Total	1,343,172	1,512,140	1,815,105
Participation	39.04	35.20	37.41

(Source: U.S. Census of Population, Michigan, Social and Economic Characteristics.)

Within the industry groups, the service trades registered a gain of 246,124 out of the total of 471,933 (<u>See</u> Table - III). A substantial employment gain of 81,011 also took place in the retail trades. Both of these gains are population related and reflect not only the aggragate population increase but the spread of urbanization with its higher densities. The manufacturing industries increased 56,970 in employment, in spite of a 55,988 lost in the transportation equipment category. The metals industry (primary and fabricated) made a gain of 18,823, but the food industry rather surprisingly lost 5,288 in employment. Textiles and chemicals made modest gains of 4,952 and 2,743 respectively.

The wholesale industry, also reflecting increased urbanization, made an employment gain of 32,811. Another significant gain of 28,048 appeared in public administration. Here the incorporation of new governmental units during the 1950-70 period and the increased span of governmental services are the basis for this upturn in employment. Professional and related employment more than doubled, increasing 26,121. In the construction industry, a 24% gain of 15,959 workers took place. The mining industry (largely gravel pits) made a modest increase in employment of 983.

Agricultural, forestry and fishing employment suffered a progressive decline from 30,422 to 15,265 over the 20 years, roughly a 50% loss. The process of urbanization not only eliminated former farm land but also made the cultivation of some other farm lands unattractive economically. Forestry in Southeastern Michigan provides a meager amount of employment. The fishing industry has suffered decline in numbers due to the impact of pollution on former favorable fishing grounds.

The most significant 20-year trend in the Southeastern Michigan economy has been the proportional decline of manufacturing employment, from 45.8% to 36.8%. Among the non-manufacturing industries, service employment increased from 17.1% to 26.2% of the total, while the combined wholesale and retail trades increased their share from 17.7% to 19.4%. The decline in manufacturing as a part of total employment and the increased share in services and grade have been a national trend. This has greater significance in the Southeastern Michigan area due to its historical record of a high proportion of employment in manufacturing. For some years now, the overall trend among large urban areas of the nation has been in the direction of greater uniformity of economic structure. Each area seems to tend to become more

Table - III

Industry Group	1950 #	1970 #	1970 %Total	1950-1970 Change	1990*	1990 %Total
Agriculture, Forestry and Fishing	30,422	15,265	0.8	-15,157	11,900	0.5
Mining	1,147	2,130		983	2,600	
Construction	65,115	81,074	4.5	15,959	94,500	3.9
Manufacturing	610,252	667,222	36.8	56,970	702,300	28.8
Food	22,092	16,804		- 5,288	14,200	
Textiles	2,305	7,257		4,952	12,000	
Chemicals	16,721	19,464		2,742	25,300	
Metals	73,032	91,855		18,823	110,200	
Transp. Equip	355,443	299,455		- 55,988	296,800	
Other Kinds of Manufacturing	142,915	232,387		89,472	244,000	
Wholesale	37,681	70,492	3.9	32,811	86,700	3.6
Retail	200,513	281,524	15.5	81,011	352,600	14.5
Services	229,133	475,257		246,124		
			28.8		827,200	33.9
Professional, etc.	20,571	46,692		26,121		
Public Administration	42,774	70,822	3.9	28,048	136,500	5.6
Other Industries	105,564	104,627	5.8	937	223,600	9.2
Totals	1,343,172	1,815,105	100.0	471,933	2,437,900	100.0

* Developed from GLBFS and SEMCOG projections, adjusted.

Source: U.S. Census of Population, Michigan, Social and Economic Characteristics.

self-sufficient while maintaining its distinctive economic speciality, but at a reduced rate of dominance. And each is impelled to produce a wider range of goods and services because of increasing population. On the one hand, the growth of the Southeastern Michigan area has been spurred by the economic demands of the nation for motor vehicles, machine tools, chemicals, steel, drugs and other manufactured products. On the other hand, it has been pushed ahead by the mounting size of its population and the increased demands of its citizens for an ever-widening variety and a greater volume of goods and services.

Personal income in the area has increased in line with employment gains and greater economic activity, (See Table - IV). From 1950 to 1969, it mounted from $10,435.1 million to $18,055.6 million in terms of 1970 dollars. This was a 73% increase. Per capita income in this period increased from $3,029 to $3,722, up 23% . It is significant to note, however, that area per capita income declined in relation to national per capita income, dropping from a ratio of 1.29 to 1.12 in 1962.

3. Projected Economic Development.

With continued economic growth in Southeastern Michigan at a reduced rate, total employment is projected to rise to 2,437,900 in 1990, (See Table - III). This represents a gain of 622,795 or 34.3% over 1970, compared to a 42.6% gain in the 1950-1970 period. The Great Lakes Basin Framework Study projected the total employment of the southeastern Michigan area (4.1) in 1990 to be 2,624,600, covering 9 counties. The figure projected for the 7-county area of SEMCOG by the Battelle Memorial Institute was 2,381,400. Table IV presents the 1990 employment projection as 2,437,900, which is an adjustment of these previous projections and is line with the revised projected population for 1990.

Changes in the ratio of various industry groups to total employment are of significance. Manufacturing drops from 36.8% to 28.8% of total employment. Transportation equipment, though gaining in numbers, remains about the same (12.1%) in relation to total employment, but drops from 44.9% to 42.3% in relation to manufacturing employment. The combined services and professional category rises from 28.7% to 33.9%, reflecting the large employment increase of over 306,000 in these fields. Public administration employment also continues to take a larger percent of the total, increasing from 5.8% to 9.2%. Construction, wholesale and retail

employment, while gaining in numbers, are expected to constitute smaller proportions of total employment in 1990.

Table - IV

AREA INCOME DATA

	1950#	1959#	1969*	1990#
Total Personal Income (in 1000's of 1970$)	10,435,120	13,324,598	18,055,556	50,351,367
Per Capita Income (in 1970$)	3,029	3,134	3,722	7,546
Per Capita Income (as U.S. Ratio)	1.29	1.14	NA	1.09

* From 1970 U.S. Census

\# Adapted from Great Lakes Basin Framework Study

Total personal income (in 1970 dollars) is projected to rise from $18,055.6 million in 1970 to $50,351.4 million in 1990, (See Table IV). Percapita income will increase from $3,722 to $7,546 in 1990, again in terms of 1958 dollars. Despite this dollar increase, the ratio of per capita income to national per capita income is projected to decline from 1.14 in 1959 to 1.09 in 1990.

Since the 1950's in Southeastern Michigan, it is evident that the area economy has been moving out of a dominant industrial character and changing into a post-industrial development period. In the national economy as a whole, the role of manufacturing activity has been undergoing significant change; this change has had its impact on the area economy. A further diversification is projected for 1990 in the area. This shift mirrors the maturing of the Southeastern Michigan economy into a more modern metropolitan character. Employment in the service trades and the professional ranks will continue to be marked, due both to the increased demands of a larger population

and the declining position of manufacturing in the total economy. But in the area, manufacturing is projected to hold a significant place, due to the expected level of consumer demand for motor vehicles and other area durable goods. However, the shift from a heavy concentration of employment in manufacturing to greater amounts of service, professional and other people-serving categories is projected to take place at a somewhat slower pace than anticipated previously.

4. Population Growth and Projection.

Over the 20 year period from 1950 to 1970, the Southeastern Michigan area registered a population growth of 1,411,089, (See Table - V). This constituted a 41.0% increase. Most of the growth, however, was centered in the three central counties of Wayne, Oakland and Macomb, where 91.1% of the area's increase took place. Among the outlying counties, Washtenaw with a gain of 99,497 (73.9%) was outstanding. St. Clair County gained 28,576; Livingston, 32,242 and Monroe, 42,812 during the 1950-1970 period.

With increased employment and continued urbanization, the area is projected to generate a sizable population growth by 1990, but at a lower rate of increase. The projected population for the full nine-county area in 1990 is 6,291,300, an increase of 1,439,952 but representing a 29.6% gain as compared to 41.0% in the previous 20-year period. (See Table VI).

The 1990 population projection takes into account the lower birth rate revealed by the 1970 Census. It assumes that age group fertility behavior in the area will continue to move in the direction of convergence with the anticipated national fertility behavoir. Although on the basis of an active and expanding economy, it is expected that some population growth will come as a result of in-migration, the overwhelming portion of the 1970-1990 gain will come as a result of natural increase - excess of births over deaths. Rural and professional families will continue to be drawn to the southeastern Michigan area due to its economic magnet; but some people, professionals particularly, are always transferring out of the area to other major urban centers of the country. Little change, if any, is anticipated in mortality rates, which are already low in this part of Michigan.

Table - V

1950 - 1970 POPULATION GROWTH

County	1950	1970	Change Number	%
Lenawee	64,629	81,051	16,422	25.4
Livingston	26,725	58,967	32,242	120.6
Macomb	184,961	625,309	440,348	238.1
Monroe	75,666	118,479	42,812	56.6
Oakland	396,001	907,871	511,870	129.3
St. Clair	91,599	120,175	28,576	31.2
Sanilac	30,837	34,889	4,052	13.1
Washtenaw	134,606	234,103	99,497	73.9
Wayne	2,435,235	2,669,604	234,369	9.6
TOTALS	3,440,259	4,851,348	1,411,089	41.0

Table VI

1990 POPULATION PROJECTION

SE Mich. Area	1950	1960	1970	1990
TOTALS	3,440,259	4,291,457	4,851,348	(Projected) 6,291,300 [1]
20-year Gains			1,411,089	1,439,952
% Gain for 20 years			41.0	29.6
TOTAL EMPLOYMENT	1,343,172	1,512,140	1,815,105	2,437,900
Participation Rate	39.0	35.2	37.4	38.7

Table - VII

POPULATION: WORKING AGE CORE

	1950		1960		1970		1990
	M	F	M	F	M	F	M & F
Ages 25-44 % Total	31.1	33.1	27.4	28.3	23.0	24.1	29.8

[1] This figure applies to the full area of the 9 counties of the Southeastern Michigan region (subarea 4.1 of the Great Lakes Basin Study). The projections for the hydrologic areas of the southeastern Michigan region do not include all the territory and population in subarea 4.1. On the basis of the 1970 Census of the 9 counties, a total of 124,099 people lived in southeastern Michigan, but outside these hydrologic areas. This number is projected to rise to 161,031 in 1990, thus making the population of the total of the 9 counties 6,291,300.

The participation rate (number of employed people in relation to total population) is projected to rise slightly from 37.4 per hundred in 1970 to 38.7 in 1990. (See Table - VI). This rise - in the face of a decline in rate from 1950 to 1960 - is expected to rest on greater employment of females and smaller families.

By 1990, the core-age working group (people from 25 through 44 years of age) is expected to reverse the 1950-1970 decline in percentage of total population, and recover a good portion of its loss. (See Table - VII). In 1950, there were 31.1% of the males and 33.1% of the females in these age brackets. In 1970, the rates were 23.0% and 24.1%, respectively. By 1990, it is projected that 29.8% of the total population (both males and females) will be within this core-age working group.

5. Water Dependent Industries.

The southeastern Michigan area contains a number of manufacturing industries where water is an important factor in production. Water use in these economic enterprises is for three major purposes: (1) Porcessing products, (2) cooling, and (3) sanitation, service and boiler feed. For these types of water-dependent industries, both the access to water in sufficient supply and of proper quality, and also adequate means for satisfactory disposal of used water and wastes are of signal importance in plant location and operation. Quality of water is a vital factor in production for such industries as food processing, brewing, soft drinks, and biological and pharmaceutical supplies. Such manufacturers require assurance of the purity of water that they incorporate into their products. Water for washing and cleaning purposes in relation to their products is required in large amounts by such manufactures as dairy products and meat packing. Likewise, manufacturing plants with their own power plants and heating equipment need above normal supplies to feed their boilers.

Different manufacturing enterprises in the southeastern Michigan area use varying amounts of water in the processing of their products. A certain amount of water is incorporated in the products of the food canning, soft drink, soap making and beer industries. The paper industry utilizes a large supply of water as an agent in the process of production.

Industries that need water for cooling purposes are the largest users of water. Steel making, chemical production and oil refining are the types of manufacturing that depend heavily on water for cooling purposes.

All manufacturing plants require water for sanitation purposes; the greater the employment, the greater the consumption. The huge automobile manufacturing plants in southeastern Michigan, with employment running from 2,000 up to 20,000, thus make considerable demands for water supply.

In Michigan as a whole, the greatest water intake, in terms of millions of gallons per year, has been in five industry groups: Primary metals, chemicals and allied products, paper and allied products, transportation equipment, and petroleum and coal products. Since the southeastern area of the state contains more than half of Michigan's manufacturing employment, the same list of heavy water intake industries applies here.

In this area, a number of plants that require a large amount of water have located along the Detroit and Rouge rivers. Such steel, rubber, pharmaceutical, and other metal industries either draw water directly from the rivers for cooling and processing purposes, or discharge water directly into the rivers, treating their wastes beforehand. Some both take in and discharge water.

There are 20 types of manufacturing enterprise in southeastern Michigan that are classified as using large amounts of water in their products or for processing and cooling. (See Table - VIII). Those with the largest 1967 employment were the machine tool and accessories industry and the metal fabricating industry. Iron and steel forgings stood third; the three types together accounted for 73% of employment in the total group. Food products and the rubber industry comprised 25,500 or 13% of total employment in the group.

These 20 industry groups totaled 180,500 employment which was 27.6% of manufacturing employment. Thus over one fourth of the total manufacturing employment was engaged in types of manufacture that utilized large amounts of water.

According to the 1970 Census, employment in 3 of the major water using industry groups totaled 128,133, by residence rather than place of work of the employee. (See Table - IX). Wayne, Oakland and Macomb counties accounted for 111,061 of these, indicating that these types of water-using manufacturers were largely concentrated in the 3 central counties.

By 1990, it is projected that employment in these 20 large water-using industries will total 227,000 as compared to 180,500 in 1967. In some of these manufacturers, the quality of the water utilized will have an appreciable

Table - VIII

SOUTHEASTERN MICHIGAN
1967 EMPLOYMENT IN MANUFACTURING INDUSTRIES
USING LARGE AMOUNTS OF WATER

SIC & INDUSTRY	EMPLOYMENT*
20 Meat & Dairy Products; Canned, Cured & Frozen & Beverages	13,000
249 Misc'l Wood Products	1,100
26 Paper & Allied Products	6,500
279 Photoengraving	400
28 Ind'l Chemicals; Soap, etc; Paints & Chem. Preparations	10,200
29 Petroleum & Coal Products	1,300
30 Rubber & Plastic Products	12,500
331 Blast Furnaces, etc.	27,300
339 Iron & Steel Forgings	3,500
34 Metal Stampings; Plating & Polishing; Metal Coating & Misc'l Products	47,500
354 Machine Tools & Accessories	57,200
TOTALS	180,500

*(Source: 1967 Census of Manufactures.)

effect on the plant cost of water treatment before use, as well as after use.

6. Impacts of Urbanization on Storm Water Run-off.

Since 1950, in the southeastern Michigan area the process of urbanization has resulted in the construction of buildings and structures that have contributed greatly to storm water run-off. In this period, over 80 suburban shopping centers of regional and community size have been erected. In addition to the ground coverage of these thousands of stores and shops in concentrated areas, the paved parking lots are of even greater significance. In 1970, these 80 shopping centers (largely concentrated in Macomb, Oakland, Washtenaw and Wayne Counties) have provided over 166,000 parking spaces. Increase and spread of population since 1950 has generated the erection of over 400,000 homes, over half of which are free-standing, single residences. The resulting covered areas have made their contribution to storm water run-off. The construction of a dozen or more large manufacturing plants, covering 500,000 to 2,000,000 square feet - in addition to their attendant parking lots - have augmented the storm water run-off problem. A final major consideration, in this connection, has been the construction of an expanded freeway and expressway system in southeastern Michigan. Storm drainage from these paved facilities has added even more to the drainage system and the disposal of these waste waters.

With increased employment and continued population gains, the urbanization process by 1990 will create even greater needs for storm drainage facilities and the treatment of an increased amount of run-off.

7. Summary and Conclusions.

The southeastern Michigan area has grown economically and in population since 1950 (and before) with no really serious shortage in water supply. At times, in summer, some communities have limited lawn and garden sprinkling, but with the expanded supply provided by the Detroit Metropolitan Water Service such restrictions no longer are required. And with the development of the Lake Huron source for water supply, the domestic, industrial and municipal water needs of the vast majority of people in the area will be assured.

Manufacturing enterprises in the area have been able to utilize the surface water supply with little difficulty. Those that find it necessary to treat the water before use in their products (such as the pharmaceutical industry) face a cost in such treatment, but in general such cost is only

Table - IX

1970 EMPLOYMENT, BY RESIDENCE, IN SELECTED MANUFACTURING INDUSTRIES USING LARGE AMOUNTS OF WATER*

County	Metal Industries	Food & Kindred	Chemical & Allied	Total
Lenawee	2,130	215	429	2,774
Livingston	1,139	53	183	1,375
Macomb	14,879	2,293	2,397	19,569
Monroe	3,192	279	455	3,926
Oakland	12,045	1,765	3,003	16,813
St. Clair	4.028	491	934	5,453
Sanilac	741	328	22	1,091
Washtenaw	1,689	256	498	2,443
Wayne	52,012	11,124	11,543	74,679
TOTALS	91,855	16,804	19,464	128,123

*(Source: 1970 U.S. Census, Michigan, General Social and Economic Statistics.)

a small fraction of the total production and marketing process. Boiler feed, cooling and processing water is widely utilized in the area directly from the intake source without treatment. Many outlying communities, with their populations and economic enterprises, that are currently isolated from the Detroit system water supply, will by 1990 have easy access to the enlarged metropolitan system.

It is highly unlikely that the Southeastern Michigan manufacturing economy will be sharply altered by a change in manufacturing mix. Large water users, such as textiles, are not congenial to the area, due to geography and climate and to the high wage rates prevalent in the area. Due to source of supply, the lumber industry has no prospects for expansion here. The food industry has been declining in employment and its future growth is limited by economic source of supplies. The petroleum and coal products industry, likewise, is not due for expansion to any large degree, again due to the distant sources of raw materials. The area is so favorably located as to source of water supply that none of the current major economic activities will suffer from lack of access to water.

The economy of re-using treated waste water instead of surface supplies will be considered later in connection with examination of alternative area systems.

B. Delineation of Wastewater Management Alternatives.

1. Service Areas.

The service areas for the various wastewater management alternatives vary to some slight degree, due to type of treatment, collection systems and lagoon areas. All, however, conform to the boundaries of the anticipated urbanized area of the southeastern Michigan region in 1990. (It could well be expected that the land disposal areas in Huron and Tuscola Counties might be utilized to handle the sanitary and storm wastewater generated within these two areas, with slight modifications.)

2. Land Requirements.

There are greater variations in the land requirements of the alternative systems presented. All have a common requirement of 23,500 acres for collection and storage of storm run-off. The land needed for new and expanded treatment plants (both municipal-industrial for wastewater and stormwater treatment) runs from zero acres for the Land Irrigation Treatment-Alternative 1 to 1,382 acres each for the Combination Wastewater Treatment Systems. (See Table - X). Acreage requirements for aeration and storage lagoons runs from zero for 7 of the alternatives to a minimum of 6,210 acres for Combination Wastewater Treatment-Alternative 3, and to a maximum of 93,174 acres for this purpose in the Physical-Chemical for Stormwater and Land Irrigation Treatment-Alternative 2.

The Land Irrigation Treatment - Alternative 1 calls for 759,538 acres or nearly 1,187 square miles of land in southeastern Michigan. The next largest amount is required by the 2nd Land Treatment Alternative: 414,446 acres. Three of the systems each need about the same amount of land: the second Advanced Wastewater Treatment alternative (28,083 acres), and the first and second Independent Physical-Chemical Systems. Three of the systems require from 30-31,000 acres, another needs 40,000 and still another calls for 69,000 acres. The 4th Combination Wastewater Treatment Alternative (with lagoons) requires over 170,000 acres.

3. Land Costs.

The data on estimated land acquisition costs, by types of land use in each system, are presented in Table - XI. These costs run from a minimum of around $124,000,000 for each of the first two Independent Physical-Chemical Treatment Systems to a maximum of $1,220,057,000 for the Land Irrigation Treatment - Alternative 1. Against these figures, the cost

Table - X

LAND REQUIREMENTS FOR WASTEWATER DISPOSAL SYSTEMS
(In Acres)

	Storm Run-off, Col. & Storage	Wastewater Treatment: Treat. Plants	Wastewater Treatment: Aer. & Storage Lagoons	Wastewater Treatment: Irr. System	Sludge Disposal: Land Fills	Sludge Disposal: Surface Spreading	Total Acres
AWT-1	23,500	1,382			6,487		31,369
AWT-2	23,500	1,382			3,201		28,083
IPC-1	23,500	970			3,431		27,901
IPC-2	23,500	897			3,528		27,925
IPC-3	23,500	897			15,791		40,188
LAND-1	23,500		93,174	597,530	2,040	43,294	759,538
LAND-2	23,500	550	41,279	303,280	2,234	43,603	414,446
C-1	23,500	1,213			5,333		30,046
C-2	23,500	1,288			5,565		30,353
C-3	23,500	1,188	6,210	28,890	5,432	4,526	69,746
C-4	23,500	1,058	18,552	105,420	4,899	17,041	170,470

of acquiring land for new and expanded treatment plants appears as a minor item. The 2nd Land Treatment alternative calls for only 550 acres at a cost of $825,000 to locate 4 stormwater treatment plants. At the upper end, the two AWT alternatives each requires 1,382 acres at a cost of $9,588,500 to locate and expand 10 plants in all.

4. Capital Costs.

The initial capital costs of each alternative system are presented in Table - XII, along with operational, replacement and debt retirement costs. Listed in the order of highest initial capital costs, it is significant that the 1st Land Treatment - Alternative is the most expensive - $5,759,000,000 - as was also true for the single capital cost item of land acquisition (See Table - XI).

The 3rd Independent Physical-Chemical Treatment System (IPC - #3) carries the lowest capital costs: $3,987,000,000. There is a very considerable difference of $1,762,000,000 between the alternatives with the highest and lowest capital costs. It is interesting, if not significant, to note that the 2 AWT systems both have lower annual replacement costs that the IPC - 3 system. The differences are less than one million dollars in each case.

5. Labor Costs.

The various alternative systems proposed require from 1,606 (Land Treatment - Alternative 1) to 3,744 persons (Advanced Wastewater Treatment - 2) to operate the respective facilities. Table XIII indicates these manpower requirements and the corresponding pay rolls. The boost to the southeastern Michigan economy provided by a system pay roll of from $20 to $46 million dollars annually is of impressive economic significance.

The Land Treament - Alternative 1 carries the lowest manpower requirement (See Table - XII). On the other hand, the highest labor requirement (3,744) of AWT - 2 carries a total capital cost which is very close to the mean of the 11 systems. The manpower requirements categories run from superintendents, supervisors and foremen to laboratory technicians, laborers and clerks and are presented later in Table - XVI.

Table - XI

LAND COSTS: Plant Sites, Landfill and Irrigation Areas, Storm Water Collection & Storage

	Acres	Cost
AWT-1		
7 Wastewater Treatment Plants	1,052	$ 9,093,500
3 Stormwater Treatment Plants	330	495,000
Landfill Areas	6,487	9,730,500
Stormwater Storage System	23,500	117,500,000
TOTALS......	31,369	$ 136,819,000
AWT-2		
7 Wastewater Treatment Plants	1,052	9,093,500
3 Stormwater Treatment Plants	330	495,000
Landfill Areas	3,201	4,801,500
Stormwater Storage System	23,500	117,500,000
TOTALS......	28,083	$ 131,890,000
IPC-1		
3 Wastewater Treatment Plants	640	960,000
3 Stormwater Treatment Plants	330	495,000
Landfill Areas	3,431	5,149,500
Stormwater Storage System	23,500	117,500,000
TOTALS......	27,901	$ 124,104,500
IPC-2		
6 Wastewater Treatment Plants	567	$ 1,277,500
3 Stormwater Treatment Plants	330	495,000
Landfill Areas	3,528	5,292,000
Stormwater Storage System	23,500	117,500,000
TOTALS......	27,925	$ 124,564,500
IPC-3		
6 Wastewater Treatment Plants	567	$ 1,277,500
3 Stormwater Treatment Plants	330	495,000
Landfill Areas	15,791	23,686,500
Stormwater Storage System	23,500	117,500,000
TOTALS......	40,188	$ 142,959,000
LAND-1		
Stormwater Storage System	23,500	$ 117,500,000
Land Irrigation of Treated Wastewater	597,530	896,295,000
Treatment & Storage Lagoons	93,174	139,761,000
Landfill Areas	960	1,440,000
Surface Sludge Spreading	43,374	65,061,000
TOTALS......	759,538	$1,220,057,000
LAND-2		
4 Stormwater Treatment Plants	550	$ 825,000
Wastewater Treatment & Storage Lagoons	41,279	206,395,000
Land Application of Sewage Sludge	43,639	65,458,500
Land Irrigation of Treated Wastewater	303,280	454,920,000
Sanitary Landfill	2,198	3,297,000
Stormwater Storage System	23,500	117,500,000
TOTALS......	414,446	$ 848,395,500

Table - XI (continued)

C-1		Acres	Cost
6 Wastewater Treatment Plants		883	$ 2,752,500
3 Stormwater Treatment Plants		330	495,000
Landfill Areas		5,333	7,999,500
Stormwater Storage System		23,500	117,500,000
	TOTALS......	30,046	$ 128,747,000

C-2		Acres	Cost
7 Wastewater Treatment Plants		958	$ 3,215,000
3 Stormwater Treatment Plants		330	495,000
Landfill Areas		5,565	8,246,000
Stormwater Storage System		23,500	117,500,000
	TOTALS......	30,353	$ 129,456,000

C-3		Acres	Cost
5 Wastewater Treatment Plants		858	$ 3,065,000
3 Stormwater Treatment Plants		330	495,000
Wastewater Treatment & Storage Lagoons		6,210	31,050,000
Land Application of Sewage Sludge		4,526	6,789,000
Land Irrigation of Treated Wastewater		28,890	43,335,000
Stormwater Storage System		23,500	117,500,000
Landfill Areas		5,432	8,148,000
	TOTALS......	69,746	$ 210,382,000

C-4		Acres	Cost
4 Wastewater Treatment Plants		508	$ 2,540,000
4 Stormwater Treatment Plants		550	825,000
Wastewater Treatment & Storage Lagoons		18,552	92,760,000
Land Application of Sewage Sludge		17,041	25,561,000
Land Irrigation of Treated Wastewater		105,420	158,130,000
Sanitary Landfill		4,899	7,348,000
Stormwater Storage System		23,500	117,500,000
	TOTALS......	170,470	$ 404,664,000

Table - XII

CAPITAL COSTS OF ALTERNATIVE SYSTEMS
(In Millions of $)

System	Initial Capital Cost	Annual Capital Cost	Annual Replc. Cost	Annual Op. & Maint. Cost	Total Annual Cost
LAND-1	5,749.	339.5	5.8	181.4	526.7
LAND-2	5,113.	302.6	4.4	124.4	431.4
C-4	4,634.	273.7	3.3	115.8	392.8
C-3	4,335.	256.0	4.7	121.4	382.1
AWT-2	4,244.	250.7	2.6	121.4	374.7
AWT-1	4,237.	250.2	2.3	117.6	370.1
C-2	4,189.	247.4	3.6	117.6	368.6
C-1	4,175.	246.6	3.7	114.8	365.1
IPC-1	4,098.	241.8	4.7	110.9	357.4
IPC-2	4,040.	238.6	5.6	113.4	357.6
IPC-3	3,987.	235.5	3.0	108.1	346.6

C. Economic Parameters.

1. Land Use Compatibilities.

(a) All the alternative systems call for a large surface storage area in Macomb and in Monroe Counties. The two consulting firms have recommended different but adjacent sites for these storage-equilization areas. In Macomb County, the Bauer firm recommends a 2,000-acre site in Chesterfield Township, bounded by 23-Mile and 25-Mile Roads on the south and north, and by North Road and the Grand Trunk Railroad on the west and east. Within this proposed site, there is some urban development on the northwest side - along Chapman and Fairfield Roads. A small urban cluster has also developed inside the area at the southeast corner - along M-29, which is 23-Mile Road. The site is paralleled by the Grand Trunk Railroad on the southeast side, and this serves as a separator from developed or developable land. Some urban development has taken place just outside the site, along US-25 on the southeast side. To some extent, urban development has also appeared near the site, along North Road on the west side of the storage area, running south from 23-Mile Road. South of the site, rather heavy urban development is on the ground on the west side of the Grand Trunk Railroad. What is largely open country continues to exist both northeast and southwest of the site.

The construction of a storage lagoon at this site should have no serious impact on the surrounding area with one exception. The Huron-Clinton Metropolitan Authority has been considering the establishment of a regional park in this general area. Its application for federal matching funds has been held up by the granting agency for the time being. If the storage area is established, landscaping around the border and the provision of some recreational area for picnicking and sight-seeing could well serve as a buffer and an amentity to the people of the surrounding area.

The Ayres, Lewis, Norris & May consultant study recommends a nearby site in Macomb County for the storage facility. Their first choice is a site in Ray Township, consisting for 3,210 acres in the southeast quadrant of the township. This proposal has two stretches of urban development along North Road, but otherwise seems clear of urbanization. It is, however, subject to the same question of encroaching upon the proposed Huron-Clinton Metropolitan Authority regional park site. From the standpoint of impact on existing land uses and future development, the Ayres site is preferable to the one recommended in the Bauer report.

Table - XIII

LABOR COSTS OF ALTERNATIVE SYSTEMS

System	Total Manpower Requirements	Annual Payroll*
AWT-2	3,744	$ 46,725,120
AWT-1	3,728	46,525,440
C-4	3,424#	42,731,520
C-2	3,283	40,971,840
C-3	3,223#	40,223,040
C-1	3,131	39,074,880
IPC-3	2,436	30,401,280
IPC-2	2,293	28,616,640
IPC-1	2,218	27,680,740
LAND-2	2,102#	26,232,960
LAND-1	1,606#	20,042,880

* Estimated at average of $6 per hour for 40-hour work week, or $12,480 per year. To this should be added 25% for overhead (fringe benefits.)

Excluding manpower for farming operations.

In Monroe County, the Bauer firm recommends a site in Ash Township, located between Siegler and Carleton-Rockwood Roads on the north and south, and between Telegraph and Armstrong Roads on the east and west sides. This area of 2,000 acres appears fairly open. There is some urban development at the northeast corner, adjacent to South Rockwood and some parallel to Telegraph Road at the middle of the west side. The areas to the east and south of the site compose open country, not yet developed into urban settlement. Since the site is located between Telegraph Road and I-75, however, it does have a potential for urban development.

The Ayres firm recommends a site on the opposite side of Telegraph Road in Ash Township. This 3,210-acre area has more urban development within its bounds than the Bauer site. At the north, along Carleton-Rockwood Road, through the center on both sides of Swan Creek, and at the southeast corner along Grafton Road, urban settlements have already developed. Hence from the standpoint of urban development, the Bauer site is judged more desirable for the storage area than the Ayres site.

It should be emphasized that all four site recommendations have realistic potentials for at least semi-multiple use in terms of abutting recreational areas. Picknicking, informal game areas, as well as boating could be developed at any one of the sites. In view of the relative lack of recreational areas in Monroe County, provision of such facilities in Ash Township would be especially appropriate.

(b) The land disposal sites proposed in St. Clair, Macomb, and Monroe Counties all fall almost entirely in areas designated by the Southeast Michigan Council of Governments as "agricultural reservation" areas in its adopted 1990 Open Space Plan. On the other hand, there are no data available regarding future planned land use of the areas in Lenawee, Sanilac, Huron and Tuscola Counties. It is presumed that since these areas are today predominately agricultural or open space in character and are not under urbanization pressure, that they will continue in their current uses to 1990. It should be noted that the Detroit Edison Company in February 1973 announced the purchase of a tract of 6,500 acres of land in Huron County between Bad Axe and Harbor Beach. An Edison spokesman is reported to have stated that the company acquired the land to have it available, if needed, for power plants. In St. Clair County, the land disposal area seems to eliminate

Emmett Village and to encroach upon the proposed Detroit Edison site for an atomic power plant in Greenwood Township.

(c) Six new treatment plants (stormwater and combined municipal-industrial and stormwater) are proposed by the various alternative systems. Further additions are proposed to 4 existing municipal-industrial treatment plants.

In all cases, these proposed plant sites should be buffered and land-scaped from their abutting lands, both in urban and rural areas. It is doubtful whether recreational areas would be appropriate on any of these sites due to the character of treatment plant operations.

The site for the new Plymouth Township stormwater treatment plant covers 85 areas. It is bounded on the north by Schoolcraft Road, on the south by Plymouth Road, on the east by Eckles Road and on the west by the Middle Rouge River. According to the latest (1972) SEMCOG land use map, there is a strip of new residential development along the west side of Eckles Road. Residential development has taken place on the west side of the site on both sides of Joy Road. A cemetary exists at the north central side of the area. The C & O Railroad cuts through the area, east to west, with single line spurs to manufacturing plants leading south, thus cutting up the east central portion of the site. However, there does appear to be ample room for an 85-acre storm water treatment plant.

The location of such a plant in this area should have no negative effect on the existing manufacturing plants. If the treatment plant, however, were placed so as to abut residential areas, there would probably be resentment and opposition on the part of home owners. The proximity of a storm water treatment plant is not judged to depress the value of built-up residential property. It must be recognized that the period of stormwater plant con-struction is apt to constitute a time of nuisance and confusion for nearby home owners and businesses.

The proposed stormwater treatment plant in Ypsilanti Township would re-quire 85 acres. The site is bounded on the north by Bog Road, on the south by 23-Mile Road, on the east by Chesterfield Road, and on the west by Fairchild Road. Residences are strung along Fairchild Road in the southwest sector. The site of Union Cemetary is just east of Fairchild Road. There are scattered homes along both 23- and 24-Mile Roads. There are, however, clustered urban developments in the proposed area. Hence sufficient space

exists for the 200-acre stormwater installation, with no anticipated impact on current home structures. There does appear to be some overlapping with the proposed Bauer lagoon site.

Near Adrian in Lenawee County, it is proposed to establish a new sanitary sewer plant on a site of 50 acres. This site is bounded on the north by the Norfolk and Western Railroad, on the south by the New York Central Railroad, on the east by South Wilmoth Highway, and on the west by the Raisin River. A few scattered homes exist along the east-west road that crosses the northern part of the area. On the whole, however, this is an area of open land. There should be no difficulty of locating the expanded treatment plant for combined municipal-industrial and stormwater here.

In East China Township of St. Clair County, it is proposed to construct a combined municipal-industrial and stormwater treatment plant on an 87-acre site. This site is bounded on the east and west by the Port Huron and Detroit Railroad. There are no urban developments within this area. The railroad serves as an excellent buffer. The site is far enough inland from the St. Clair River not to be under pressure for urban development. In such undeveloped territory the impact of the plant on its environs would be inconsequential.

Near the mouth of the Huron River, the largest combined municipal-industrial and stormwater treatment plant is proposed, on a site running from 350 to 540 acres. This area in Monroe County bounded on the north by Ready Road, on the south by Siegler Road, on the east by Hagerman Road and on the west by Dixie Highway. The New York Central and the Detroit, Toledo and Irontown Railroads cut across the northwest corner of this area. A string of homes has been built north and south along Hagerman Road. A few have also been constructed along Dixie Highway. Residences along Ready and Siegler Roads are few and far between. The railroads provide an effective buffer at the northwest corner. The proposed site is far enough away from the Village of South Rockwood so as to have no harmful impacts on this urban center. It is suggested, however, that buffering receive attention on this sector to prevent any handicap to future urban development. The plant site could be fitted into the proposed area very well.

The four existing municipal and industrial treatment plants that are proposed for expansion are as follows:

Detroit	added	320	acres	maximum
Wyandotte	"	100	"	"
Monroe	"	50	"	"
Port Huron	"	38	"	"

In each case, the existing plants are within or at the edge of built up urban land. Adding from 32 to 320 acres at these various sites will require in most cases the displacement of current urban uses. The impact of a larger treatment plant establishment on the abutting properties will be pronounced. Buffering and landscaping will probably be imperative. The possibility of multiple uses of such land is minimal, hence buffering should be considered where residential land abuts. Since the existing treatment plants have been on the ground and in operation for some years, the abutting and nearby property owners have had time to adjust to the existence of these installations. Enlargement, therefore, will not have a from scratch impact, but simply that of a larger operation of the kind that has existed for years.

Other land impacts must be considered when the exact locations of other proposed wastewater treatment facilities have been determined. Storage and aeration lagoons, land fills, and areas for the surface spreading of sludge will have varying effects on their abutting and surrounding territories. In all cases, buffering, landscaping and multiple use (such as recreation) should receive careful attention.

2. Water Supply.

None of the current urbanized areas and none of those projected for 1990 will be handicapped for want of water supply. The quality of surface water now provided to the developed areas requires some treatment for municipal use, and further treatment for a limited number of industrial uses. The cost of such treatment, however, forms such a minimal amount in the total production process of industries, like pharmaceuticals and brewing, that a reduction in treatment costs would not appear to offer a signal advantage to these industries.

As noted previously, the provision of an unpolluted water supply by 1990, or before, is not likely to attract new types of manufacturing enterprise to the southeastern Michigan area. The mix of industrial interprise has largely been determined by geographical location, in regard to

supply of materials, and by climate, as well as by wage rates in the established industries. Expansion of the steel industry is possible by the establishment of one or more new plants, or by the enlargement of existing steel plants. But brand new plants are not likely due to the increasingly dispersed pattern of steel making enterprises across the nation and to the utilization of smaller plants. The abortive attempts to attract new steel companies to the downriver area of Detroit and Monroe in the past indicates little chance for such new establishments. The Ford Motor Company continues to improve and expand its steel production in its River Rouge complex as do the steel companies in the downriver section of the Detroit region.

Present water supply plans for southeastern Michigan involve two 120 -inch supply lines from the new Lake Huron intake which are being constructed by the Detroit Metropolitan Water Service. The first of these large lines has been completed through St. Clair County. The second is scheduled for construction in the 1976-1980 period. In this interval, it is possible that the economics of supplying water to the area of the City of Detroit and southward down river into Monroe County may involve the re-use of treated water from the three treatment plants: Detroit-Jefferson Avenue, Wayne County - Wyandotte, and the new plant near the mouth of the Huron River. At this point intime, no data are available on the possible lower cost of supplying renovated water for re-use by municipal and industrial establishments in these areas. The concentration of industrial plants in the downriver area does present a real potential for the re-use of renovated water which could be produced by these nearby wastewater treatment plants. The added cost of providing piping of such renovated water to these manufacturing plants for re-use must be taken into consideration. Municipal re-use of such water, however, is very questionable, due to possible virus infection contents from the health standpoint and to public repugnance to such tap water use.

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1 Water Quality Criterion, National Technical Advisory Committee of Water Quality Criteria, 1968.

2 Renovated Wastewater, James J. Johnson, 1971...

According to a 1968 report, industrial water in-take in the United States is divided as follows: 90% for cooling or condensing, 8% for processing and 2% for boiler feed. [1] In the Great Lakes area, "The scarcity of water may not be so critical as to warrant the direct municipal use of renovated water in the near future....One can assume that such hygienic risk constraints would limit the operation of direct municipal use of renovated wastewater beyond circumstances dictated by economic practicality". [2]

3. Planning Priorities - Goals and Objectives.

The Southeast Michigan Council of Governments (SEMCOG) has adopted a statement of "Goals for the 1990 Regional Development Plan", which covers 7 or the 9 counties of the wastewater management study. This is the only official goals statement generated in the region to date. The general over-all goal is enunciated as follows:

> " To improve the physical and social environment of the southeastern Michigan Region - in quality and structure - so as to enable the people of the region, as individuals and as groups, to live, work, and enjoy life better with opportunity for choice of employment, economic enterprise, housing, neighborhoods and communities, educational recreation and cultural advance."

In regard to public facilities, the agency objective is:

> "To improve and protect the environmental health of the people of the Region and to organize and maintain regional systems of water supply, sanitary sewers and treatment plants, storm drainage and solid waste disposal facilities that will at least equal the environmental standards set by the State and the Nation, and will most economically serve the needs of the households and economic enterprises of the Region."

SEMCOG holds further that the development of such regional systems can aid materially in shaping the regional pattern of growth and development, since the provision of absence of such service facilities acts either to encourage or to restrain urban growth and development.

The SEMCOG objective on fiscal matters in the Region is stated as follows:

> "To assure efficient utilization of local, state, and national funds and an appropriate share of private capital for the accomplishment and support of the general regional development plan of public facilities, such as, transportation, water mains, sanitary sewers and interceptors, sewage treatment plans, storm drainage facilities, solid waste disposal, and land for parks and open space."

Each of the alternatives presented by the wastewater management study is consistent with the SEMCOG statement of regional goals and objectives. The SEMCOG goals are more people-centered in the perspective than the wastewater management alternatives, at least more explicity so. But it appears that the end situation is much the same. The objectives, in both cases, do not appear to be in conflict with each other in any way.

4. Revenue Sources and Losses.

(a) Capital Costs.

The impact of any one of the alternative systems upon the southeastern Michigan economy would be of major significance. The expenditures for land, for construction materials, for equipment and for manpower are bound to have a pronounced and expansive short-range effect upon the region's economy and certain of its economic enterprises. The initial capital costs for the various alternative systems are calculated to run from $3,987,000,000 for the 3rd alternative of the Independent Physical-Chemical Treatment System to $5,759,000,000 for the Land Irrigation Treatment - Alternative 1. (See Table - XII). Labor Costs - engineering, architectural, technical and building trades - involved in the initial capital layout are expected to run about one half the total. This means that over a fairly short range of time (5 to 10 years), a vast amount of purchasing power ($1,998,500,000 to $2,874,500,000) will be released within the regional economy. It is very likely that the labor demand for construction will require both the importation of building trade, tunnel, and other construction workers from outside the area as well as training of potential manpower within the area.

Other than the impact on the economy of these vast construction projects, it is not expected that the creation of an unpolluted water supply will have a significant effect on existing economic enterprises or on the introduction of new types of economic activity. Such changes will more than likely stem from the anticipated growth and diversification of the regional economy in the normal course of metropolitan change and development.

(b) Farm Products.

A distinctive feature of the Land Treatment system is the anticipated increase in crop production - as well as a change of crops - on land that is treated with spray irrigation. The Dow Engineering report recommends a 10-year crop rotation system, as follows:

3 years of alfalfa-brome grass
2 years of corn for grain
2 years again of alfalfa-brome grass
3 years of reed canary grass

On this background, Lee A. Christensen has projected crop yields and values, under varying assumptions. [1] He notes two major factors calculated to bring about production changes associated with spray irrigation of wastewater: (1) Change in the number of acres under crop production, and (2) Changes in cropping patterns, yield response, and drainage in these areas.

Without disposal of wastewater by spray irrigation, he estimates that 489,700 acres will be under production in 1980. With disposal, the estimate rises about 16% to 565,760 acres. There would be in addition, under disposal, 31,790 acres as support area - for lagoons, buffer strips, and other operational purposes. But more importantly, the acres under cropping would be expanded by pasture land being converted into cropland and by utilizing land heretofore idled because of insufficient drainage.

Because of wastewater application, a shift from grain crops to roughage crops is assumed. Small grains, corn for grain and soybeans will be replaced by silage and hay.

Christensen makes one variation from the Dow report on crop rotations. He estimates corn production for both grain and silage and finds that corn for silage produces a greater dollar yield than corn for grain.

He recognizes the issue of the use of all the roughage produced on the disposal sites. Due to shipping costs of such bulk materials, they would need to be utilized close to the point of production. A large increase in livestock operations near the disposal sites or the establishment of a pelletizing operation would be necessary. He also recognizes that the establishment of wastewater disposal operations at the proposed sites might disrupt the existing channels through which machinery, petroleum products, seed and fertilizer are now distributed. The number of local suppliers could be reduced through an emphasis on volume purchases, thus modifying the local economy.

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[1] Lee A. Christensen: "Land Disposal of Wastewater - An Assessment of Its Impact on the Agricultural Economy", final report, 1973.

Christensen sets up a series of six frameworks, representing different yields in 1980 cropping patterns on the proposed drainage sites. Two deal with the benchmark situation - one with and one without drainage improvement, but no spray irrigation. The next two are based on spray irrigation but assume a 10% and a 25% decrease in yields. The final two, also with spray irrigation, posit 10% and 25% increases in crop yields. The following table presents the estimates of the #1 Benchmark Framework (without either spray irrigation or drainage) and Frameworks #5 and #6, with spray irrigation and the rotation of corn for silage.

Table - XIV

1980 VALUE OF CROP PRODUCTION AND AGRICULTURAL EMPLOYMENT

	#1 Framework (Benchmark)	#5 Framework 10% increase)	#6 Framework (25% increase)
St. Clair, Monroe, Lenawee and Huron-Tuscola Sites.	$28,721,000	$46,587,000	$52,952,000
Agricultural Employment	1,360	2,976	3,382
Population Increase	4,896	10,714	12,175

From these data, it appears that under the most favorable crop production assumption (#6 - 25% increase) there would be a gain of $24,231,000 at the end of 1980, over the benchmark value. This increase, viewed in the light of the $5,749,000,000 initial cost of the Land Treatment system, amounts to a return of 0.42 percent (42/100 of 1%), which can hardly be termed even a fringe benefit on the investment!

(c) Withdrawal of Land from the Tax Base.

Each of the alternative systems would result in the withdrawal of various amounts of privately owned land from the tax base of local government (municipality, township and school district), and from the county. The minimum withdrawal would be in Wayne County for a total of 2,880 acres under the Land Treatment - Alternative #1. The maximum land taking is for an estimated 388,970 acres in the Huron-Tuscola area also under the Land

Irrigation Treatment - Alternative 1. (See Table - XV). In all the alternatives that involve land for spray irrigation, consideration should be given to allowing the land to remain in private ownership, with arrangements being made with the owners for utilization of treated wastewater by the spray irrigation method.

St. Clair County would incur the second largest displacement of land (241,044 acres), again under Land Irrigation - Alternative 1. Monroe County's losses would be next in order with 92,084 acres involved in this same system. One of the counties would be subject to the same amount of land displacement under each of the alternative systems: Oakland, 3705 acres.

5. Displacement of Residences and Roads by Land Acquisition.

The number of family residences to be displaced varies widely among the alternative systems. The largest amount would occur under the Land Irrigation Treatment - Alternative 1. The Dow report covers a total of 9,124 families to be relocated (on the assumption that all spray irrigation land will be publicly owned), at a cost of $5,000 per family, as follows:

5,298	families in	Huron-Tuscola area at a cost of	$26,490,000
2,130	" "	St. Clair County " " " "	10,650,000
1,391	" "	Monroe County " " " "	6,955,000
305	" "	Lenawee County " " " "	1,525,000
9,124			$45,620,000

Again, it must be pointed out that this huge cost could be drastically reduced if the farm land were left in private ownership and agreements reached with the owners for spray irrigation.

The displacement of families for the acquisition of land for storage an aeration lagoons and for new and expanded treatment plant sites would be of minor significance.

The existing road system will be subject to some replacement or revision, especially under the Land Irrigation Treatment alternatives. In the five counties so affected, the following State roads traverse the proposed land disposal areas:

Table - XV

ACRES REQUIRED BY COUNTIES

System	Lena	Macomb	Monroe	Oak	St. C.	Wash.	Wayne	Huron-Tusco.
AWT-1	5,720	6,425	5,860	3,705	3,539	2,995	3,505	
AWT-2	2,408	6,425	5,860	3,705	3,215	2,995	3,505	
IPC-1	2,643	6,425	5,810	3,705	3,153	2,995	3,200	
IPC-2	2,706	6,425	5,822	3,705	3,182	2,995	3,120	
IPC-3	13,343	6,425	5,822	3,705	4,408	2,995	3,120	
LAND-1	22,015	6,265	92,084	3,705	241.044	2,910	2,575	388,970
LAND-2	22,185	6,425	63,809	3,705	217,757	2,995	2,880	94,740
C-1	4,378	6,425	5,860	3,705	3,358	2,995	3,355	
C-2	4,659	6,425	5,860	3,705	3,309	2,995	3,430	
C-3	9,570	6,425	5,860	3,705	37,791	2,995	3,430	
C-4	24,777	6,425	63,859	3,705	65,079	2,995	3,300	
Most Acres	24,777 C-4	6,525 All Other	92,084 LAND-1	3,705 all	241,044 LAND-1	2,995 all	3,505 AWT-1	388,970 LAND-1
Least Acres	2,408 AWT-2	6,265 LAND-1	5,810 IPC-1		3,153 IPC-1	2,910 LAND-1	2,575 LAND-1	none for all but LAND-2

Huron County:	#19 and #53, north-south #142 east-west
Tuscola County:	#81, east-west and southwest-northeast #138, east-west and north-south
St. Clair County:	#19, north-south #21 and #136, east-west
Monroe County:	#50, east-west
Lenawee County:	#223, east-west

In addition to these State roads, a number of mile roads cut across the land disposal areas in each of the above counties. Just what road displacements and required revisions will be necessary cannot be determined until more detailed plans are developed for the establishment of the land disposal alternatives and for the large storage areas. It is imperative, however, that this situation be fully considered when judging the impacts of the various alternative systems on the involved county road networks.

6. Property Values.

To date, no data have been developed concerning the impact of new and expanded treatment plants (both municipal-industrial and stormwater) on the value of abutting and nearby residential, industrial and commercial land and structures. Public objection on the part of residential property owners in the vicinity of these plants must be anticipated. Considered and early steps should be taken to eliminate or alleviate such fears. Some community opposition has been normal in cases where sanitary landfills, airports, public parts and other such public installations have been proposed. With carefully designed buffer zones, effective landscaping and the encouragement of public pride in the community and regional value of wastewater disposal installations, many of these fears and objections can be minimized. Some studies have shown that abutting property values have not been depressed by the establishment of public parks, sanitary landfill areas and airports.

The effect of spray irrigation on adjoining property is another aspect to be assessed. Unfortunately, there are practically no experience data to depend upon. Since these irrigation areas are proposed in what is primarily farm and open country, the public pressure against such operations is apt to be of less force, but it will require consideration.

Wherever multiple use - such as recreation - can be developed in ralation to surface storage areas, the value of adjacent lands is less likely to be harmfully affected, and the cutting edge of public opposition may well be blunted. Compared to most of the other counties involved, both Macomb and Monroe are short on needed public recreation facilities.

There is a possibility that shoreline land values will be enhanced in those areas that are now adversely affected by polluted streams and bodies of water, such as, the Monroe County shoreline along Lake Erie and sections of the Lake St. Clair shoreline in Macomb County. Just how much such shoreline land values might increase cannot be determined at this time for lack of information of the impact of the current degree of pollution of the attendant waters, and of any estimate of the loss in property values over the last 10 to 30 years.

7. The Labor Market.

By 1990, the age 25-44 working core is anticipated to compose 29.8% of the total population of 6,291,300 of the regional area. This means that the overwhelming portion of the labor force will be drawn - both male and female - from this age group. With total employment projected at 2,437,000, the largest sectors are expected to be: Professional and Service, 827,200; Manufacturing, 702,300, and Retail, 352,600.

Labor demands as reflected by the 1970-1990 projections (See Table - III). are as follows:

Heavy employment gains -

305,251	professional and services
118,973	miscellaneous and other
71,076	retail
65,678	public administration

Medium and minor gains -

35,078	manufacturing
16,208	wholesale
13,426	construction [1]
473	mining

Losses -

3,365 agriculture, forestry and fishing [2]
2,655 transportation equipment

Within governmental employment (Public Administration), each of the alternative systems would add people to the city, county, and regional agency work forces. (See Table - XVI). The highest labor requirements (3,744) are attached to the Advanced Wastewater Treatment - Alternative 2. The lowest labor demand would occur in the Land Irrigation Treatment - Alternative 1, where only 1,606 people would be needed for its operation. It should be noted that this low figure does not include the number of agricultural workers needed to operate the farm lands that would be under spray irrigation. Christensen estimates that 3,382 persons would be required to man the agricultural work on the spray irrigated lands. This presumably would be the manpower requirement whether the sprayed land were under corporation management or continued in private ownership. As noted above, the net gain would be 1,644 agricultural workers.

Purchasing power provided in the regional economy by the payrolls of the alternative systems was noted in Table - XIII. The Advanced Wastewater Treatment - Alternative 2 would provide the highest payroll: $46,725,120. The lowest would be released by the Land Treatment - Alternative 1 in the amount of $20,042,880.

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[1] Manpower requirements for construction of wastewater disposal facilities under any one of the alternatives will create a bulge in construction employment over a period of several years. The heaviest employment demands would be for treatment plant and tunnel construction. By 1990, however, it is anticipated that these unusual manpower requirements will be fulfilled and that employment in this category will run around 94,500.

[2] The Land Irrigation Treatment - Alternative #1 system would increase both the amount of agricultural land under production and the amount of agricultural employment needed to farm the spray irrigated lands. Christensen estimated that under the best assumption (Framework #6), 3,382 persons would be employed in 1980 in agriculture on the land disposal areas of the five counties. It is estimated - on the basis of the ratio of acres farmed in each county - that in 1970 a total of 1,738 people were employed in the 5 counties on the land designated for spray irrigation. This would mean a gain in 1980 of 1,644 employed in agriculture. Assuming that the same level of employment on the spray irrigated land continues in 1990, the loss in the agriculture, forestry and fishing category would be 1,721 instead of 3,365 persons.

Table - XVI

SUMMARY OF MANPOWER REQUIREMENTS

ALTERNATIVE	SUPERINTENDENTS AND SUPERVISORS ($14,000-30,000)	FOREMEN ($16,000)	OPERATORS ($14,000)	ELECTRICIANS ($12,000)	MAINTENANCE MECHANICS ($12,000)	LABORATORY TECHNICIANS ($8,000-15,000)	LABORERS ($6,000-10-000)	OTHER: CLERKS, SEC'YS ($8,000-10,000)	TOTAL MANPOWER
AWT - 2	87	345	1,898	166	235	127	809	77	3,744
AWT - 1	87	343	1,883	166	235	127	810	77	3,728
C - 4	75	294	1,602	175	236	185	788	69	3,424*
C - 2	76	300	1,631	152	215	108	727	74	3,283
C - 3	73	299	1,583	154	212	122	711	69	3,223*
C - 1	68	281	1,554	146	206	103	702	71	3,131
IPC - 3	52	195	1,198	113	175	71	563	69	2,436
IPC - 2	52	203	1,071	117	172	71	541	66	2,293
IPC - 1	39	200	1,036	111	177	68	533	54	2,218
LAND - 2	43	162	843	128	155	237	486	48	2,102*
LAND - 1	29	117	526	135	135	394	255	15	1,606*

(* Excluding manpower for farming operations.)

The categories of manpower needed to operate each system are presented in Table - XVI. In general, operators and laborers predominate in each alternative. The minor numbers in manpower fall in the superintendents and supervisors categories.

The establishment of new and expanded wastewater treatment plants and other installations will create critical demands for qualified people in management and supervisory positions. Likewise, there will be a significant demand for technicians and operators. Since the construction of the plants and installations will be time-phased, the progressive meeting of operating manpower requirements should be planned in advance. If necessary, educational and training courses should be organized and operated in sequence, anticipating the completion of these installations of the agreed upon system, and the initiation of their operation.

8. Financing the Wastewater Management System.

The establishment of any one of the alternative systems will require the participation of local (municipal and township), County State and Federal agencies in various degrees of responsibility and funding. Until the costs of constructing and operating a system are allocated on a minor civil division and county (or regional) basis, it is not possible to determine just how each governmental level can finance its share of the total system. Currently, local, county and regional agencies have depended upon Federal and State grants-in-aid to help finance their wastewater management operations, as inter-locking parts of a growing regional system.

At the local unit of government level (city, village and township) in Michigan, as well as at the county level, the current methods of financing public works are: (1) General Obligation bonds, (2) Revenue bonds, and (3) Special assessment procedures. Counties are also able under law in Michigan to pledge their faith and credit to assist their minor civil divisions - or combinations thereof - to finance public works installations. Currently, the State of Michigan's "Clean Water" bonding program has about run its course; the $200 million fund is nearly exhausted. A renewal of this fund would require a favorable vote of the citizens of the State. The original fund was used largely to supplement Federal matching funds from various national agencies to Michigan agencies for sanitary sewer plants and interceptors.

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SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT STUDY. LAND DISPOSA--ETC(U)
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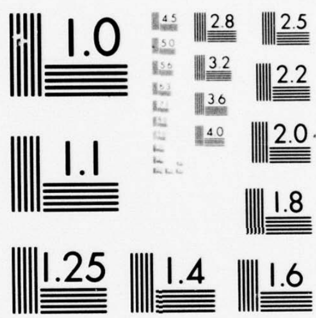

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Southeastern Michigan has been handicapped in recent years in the progress of its pollution abatement program by the withholding of Federal funds anticipated (if not pledged) for various projects. In the present situation, wastewater management programs adopted by the Congress are being cut back by the Administration.

Whatever the alternative system adopted in southeastern Michigan, it is most likely that the major governmental agencies (which either collectively or separately) will establish the system will be the Detroit Metropolitan Water Department and the various county departments of public works and/or county drain commissions.

CONCLUSION: PERSPECTIVES FOR FINAL ECONOMIC IMPACT ASSESSMENT.

The final assessment of the economic impact of each of the 11 proposed wastewater management systems can only eventually be determined within a framework of the seven following factors:

(1) Construction costs of each proposed system facilities:

(a) To be met by local, county, regional, State and Federal governments,

(b) With a temporary stimulus to the regional economy through material demands and construction employment.

(2) Annual operational and debt funding costs:

(a) To be met by the same governments,

(b) With a benefit to the regional economy through increased operational employment.

(3) Costs to municipalities, townships, school districts and counties due to removal of private land and structures from property tax rolls. (No data on hand).

(4) The agricultural manpower demands under the alternatives involving farm production under spray irrigation.

(5) The increased dollar returns from improved and increased croppage under the spray irrigation alternatives.

(6) The impact of new and expanded wastewater treatment plants, irrigation areas, and storage lagoons on abutting and nearby land and structures in terms of depressing or increasing property values. (No data on hand).

Table - XVII

COMPOSITE ECONOMIC RATING OF ALTERNATIVES

ALTERNATIVE	CONSTRUCTION COSTS	LAND COSTS	ANNUAL OPERATION COSTS	ACRES TAKEN OFF TAX ROLLS	CONSTRUCTION EMPLOYMENT PAYROLL	MANPOWER TO OPERATE	INCREASED CROP VALUES	IMPACT OF FACILITIES ON NEARBY LAND	TOTAL SCORE
IPC - 1	3	1	2	1	9	9		1	26
IPC - 2	2	2	3	2	10	8		2	29
AWT - 2	7	5	7	3	5	1		3	31
COMB - 1	4	3	4	4	8	6		4	33
COMB - 2	5	4	5	5	7	4		5	35
AWT - 1	6	6	6	6	6	2		6	38
IPC - 3	1	7	1	7	11	7		7	41
COMB - 3	8	8	8	8	4	5	4	8	53
COMB - 4	9	9	9	9	3	3	3	9	54
LAND - 2	10	10	10	10	2	10	2	10	64
LAND - 1	11	11	11	11	1	11	1	11	68

Rating Criteria

CONSTRUCTION COSTS: lowest to highest.

LAND COSTS: lowest to highest.

ANNUAL OPERATION COSTS (including replacements and debt retirement): lowest to highest.

ACRES TAKEN OFF TAX ROLLS: least to most.

CONSTRUCTION EMPLOYMENT PAYROLL: highest to lowest.

MANPOWER TO OPERATE: most to least number.

INCREASED CROP VALUES: highest to lowest.

IMPACT OF FACILITIES ON ADJOINING LAND: least to most acres in facilities.

TOTAL SCORE: most economic benefits to least, with lowest number signifying greatest benefits.

(7) Reduction of manufacturing production costs through:

(a) Access to higher quality water, thereby eliminating or reducing water treatment within the plants, and/or

(b) Access to a cheaper water supply produced by the renovation of wastewater and its re-use. (No data on hand).

(8) Impact on abutting shoreline property of pollution removal from streams and bodies of water, in terms of increased values. (No data on hand).

Since it is not feasible to construct an evaluative table which would include items for which no data are available, Table - XVII has been constructed with the use of quantifiable criteria. It should be recognized that each of the 8 items is arbitrarily given equal value, for want of a common yardstick on which all items could be measured. The scale for rating each item is self-explanatory in most cases, or noted at the bottom of the chart. The Construction Employment payroll is regarded as a benefit to the regional economy on the basis of the purchasing power it releases. Impact of facilities on adjoining or nearby land is rated simply on the number of acres required for the facilities of each alternative. The more acres so required, the more adjoining acres impacted and the greater the likelihood of negative impact.

There are several factors that at present cannot be quantified but which deserve consideration a PLUS POTENTIALS.
These apply to all alternatives and are as follows:

(1) Increased value of shoreline property due to no discharge of critical pollutants.

(2) Lower manufacturing costs due to high water quality, modifying or eliminating further in-plant treatment before use.

(3) Re-use of renovated water from treatment plant by industry.

(4) Multiple use (recreational) of large surface water storage areas,

(5) Re-use (recreational) of completed landfill areas.

(.....END.....)

HYGIENIC ASSESSMENTS OF ALTERNATIVE SYSTEMS OF WASTEWATER MANAGEMENT IN SOUTHEASTERN MICHIGAN

FOR

THE UNITED STATES ARMY CORPS OF ENGINEERS --
DETROIT DISTRICT

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April 1973

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OF

HYGIENIC ASSESSMENTS OF THE SOUTHEASTERN MICHIGAN

WASTEWATER MANAGEMENT STUDY

I. Introduction

With the rapid urbanization of much of Southeastern Michigan comes tremendous increases in the quantities of domestic sewage, industrial sewage, and urban runoff which necessitates adequate treatment and disposal.

The United States Army Corps of Engineers is in the process of studying and evaluating several alternative systems of wastewater disposal. For Southeastern Michigan alternative schemes have been designed in an effort to meet the standard of "no discharge" of critical pollutants for the 1990-2020 period.

This report represents an effort to assess the possible hygienic impacts of each of the proposed alternative plans. While efforts will be made to discuss the critical public health aspects of each of these schemes, the limitations of available knowledge and the need for further research are recognized. Hence, this can by no means be considered an exhaustive discussion of the subject. When considering the possible health hazards which may be associated with each plan, biomagnification of specific residuals and possible chronic disease manifestations can not be ignored.

In light of a need for further information in this very broad area, much of the information contained herein will capitalize on the specific expertise of the authors.

II. General Hygienic Considerations of Potential Health Hazards of Wastewater

A. Introduction

Disease hazards which are associated with wastewater are often overlooked until clinical disease or disability has been detected, either endemically or in numbers which might constitute an epidemic. A large number of subclinical or clinical diseases resulting from exposure to contaminated wastewater may either go unnoticed or be attributed to other causes. While many biological

organisms and chemical compounds are often considered to be non-pathogenic, it must be recognized that most of these agents are capable of causing some detrimental health effects, including clinical disease and death, when permitted to interact with a susceptible individual under the proper conditions. With this in mind, the presence of these organisms or substances in the water or atmosphere of our general environment should not be taken lightly.

Detailed discussion of all of the infectious or non-infectious agents which might be capable of causing human infection or disease via the wastewater or water route is beyond the scope of this study. Therefore, this discussion will emphasize selected biological or chemical agents which are of widespread concern or which, by their nature, may pose special health problems in the management of wastewater.

B. Potential biological hazards

Bacteria

While widespread outbreaks of waterborne infectious disease have been greatly reduced in this country, the organisms responsible for such outbreaks can not be ignored since they remain a potential threat to our population should sanitary conditions be reduced. Bacteria of the genus *Salmonella* include a wide variety of species which have been implicated in waterborne disease outbreaks. *Salmonella typhi*, the causative agent of typhoid fever, and *S. enteritidis*, of which there are more than 1500 serotypes, many responsible for varied diseases, including acute gastroenteritus, have been encountered in wastewater. While *S. typhi* is only occasionally isolated from wastewater, various serotypes of *S. enteriditis* are much more common and are often implicated as disease causing agents. The type species, *S. cholerae-suis*, is associated primarily with swine and does not appear to represent a significant human health problem (1).

Numerous outbreaks of bacillary dysentary caused by

Shigella sp. have been attributed to wastewater and polluted waters. Cholera, an often fatal disease caused by Vibrio comma, is a disease of tremendous public health importance in areas of the world where it is endemic. While now not a major health problem in the U.S., this disease has occurred historically in this country. The application of principles of basic sanitation can successfully prevent the spread of this disease. Mycobacterium tuberculosis has been isolated from wastewater, especially at locations in the vicinity of institutions which treat tubercular patients and near slaughterhouse or dairy industries (2). Human cases of tuberculosis which involved the aspiration of contaminated water by swimmers have been reported.

Leptospira sp., organisms which cause leptospirosis, may be present in water and wastewater (3). Most of the common species which cause this disease enter the water through animal urine. A significant proportion of these organisms come from areas which are frequented by infected rats or domestic animals (3). A large number of human cases have been recorded in areas where humans had been swimming in water accessible to cattle and swine (1).

Other organisms which have been implicated in human waterborne disease include some of those which are normally considered to be nonpathogenic. There are reports of disease caused by enteropathogenic Escherichia coli and specific strains of Pseudomonas sp. These organisms are almost universally found in wastewater and might be implicated in a large number of cases of gastroenteritis considered to be of unknown etiology (1).

Parasitic agents

Any urban wastewater may contain cysts of Entamoeba histolytica, since almost all areas contain some persons who have amoebic dysentery and who excrete the organism. These cysts are resistant to a large number of adverse conditions and, therefore,

are capable of long-term survival in the aquatic environment. The determination of the actual prevalence of this organism is made quite difficult by the large number of subclinical infections.

Roundworms, such as Ascaris lumbricoides, may produce eggs which, when excreted by an infected individual, may become a hazard in sludge disposal. Tapeworms, such as Taenia saginata or Taenia solium, require the ingestion of excreted eggs by an intermediate host, cattle, and swine, respectively. These organisms could present a hazard by successfully continuing their cycle of transmission through the ingestion by these farm animals of contaminated plants grown on spray irrigated fields or on sites of land disposal of sludge. Additional consideration might be given to other tapeworms, such as Diphyllobothrium latum, which is transmitted through an aquatic environment via fish and crustaceans. While human schistosomiasis is not a problem in this country, a form of this disease is transmitted by waterfowl and is responsible for the very annoying, and sometimes serious, local itching or irritation called "swimmer's itch".

Fungi

Fungi which are potential pathogens have been isolated from wastewater and polluted water (3). Although a wide variety of fungi are capable of causing very severe infections and disease in man, the presence of these organisms in wastewater has long been ignored. While many of these agents are dispersed throughout the environment, there is a possibility that a concentrated source of these organisms, such as wastewater, would present hygienic hazards to individuals subject to special exposure. Particular problems might be caused by the wind dispersal of spores during spray irrigation or sludge land disposal operations.

Viruses

Viruses probably constitute a major and relatively

uncontrolled hazard in water. While, in many respects, viruses behave as other pathogens, they do have some distinct features.

1. Viruses, in contrast to other microbes, cannot multiply except within living hosts. It appears that under field conditions host specificity is moderate or very restricted; that is, man might share some viruses, such as reoviruses, with other animals, but there is yet no good evidence that he does with plants, bacteria, fungi, protozoa or few-celled metazoa. Therefore, viruses can be maintained, destroyed or concentrated in wastewater, but they cannot multiply.

2. The minimum infectious dose of a virus for man is the minimum infectious dose detectable by any other means. Epidemiologic evidence suggests that a single infectious dose for a cell culture can also be an infectious dose for man (4).

3. The health hazards of viruses in water are not limited to those situations where water could or does serve as a vehicle for the continued transmission of endemic or epidemic disease. Viral contaminants are significant hazards even if they are present infrequently or at low levels and if they seed a susceptible population or infect a susceptible individual.

4. Viruses may have delayed effects, or disease may occur so long after infection, that cause-effect relationships are at present unknown or conjectural. For example, viruses may be oncogenic (tumor inducing) or teratogenic (inducing birth defects) and some viruses, presently considered only as etiologic agents of acute disease, may produce chronic effects such as diabetes or delayed motor disability. A particularly challenging consideration is the currently unknown prevalence and significance of the so-called "slow viruses".

Viruses as Hygienic Risks in Water

Studies of water supplies, wastewater and, to a lesser extent, recreational water have identified enteric viruses, resulting from fecal contamination as the major viral pollutants of water. These viruses include polio-, coxsackie- and echo-viruses, collectively known as enteroviruses, of the picornaviral group; the virus of infectious hepatitis; adeno-; and reoviruses. Viruses other than enteric, such as some excreted in the urine, may occur in water but evidence is questionable that water plays a significant role in transmitting their infections.

Poliovirus has been the most widely studied of the viruses that are commonly water-borne. While its presence in sewage is frequent, widespread, and acknowledged, its role as a cause of water-borne disease is highly questionable and established for only a single epidemic. However, one can only speculate about water as a source for introducing poliomyelitis as an infection as opposed to maintaining it as an epidemic. Man appears to be the only natural host, although primates can be infected. While infection is widespread, disease is relatively rare. Disease, when it occurs, however, is erratic in terms of death or severity of permanent or temporary damage to the central nervous system.

Poliomyelitis ought to be the least of the viral hazards since safe, inexpensive, effective control is available through vaccination. If an active vigorous campaign is re-instituted and maintained, wild polio-virus strains should disappear from the environment. There is evidence that it disappeared in countries practicing widespread immunization with either killed or live-virus vaccine. Whether poliomyelitis can be so universally obliterated that there can be consideration of abandoning or restricting immunization, as was recently decided with smallpox, is speculative, but possible by the reference year 2020. It is mentioned because water might then be a vehicle for reintroducing

the virus to an unprotected population. Except for infectious hepatitis and slow viruses, where adequate data are lacking, the susceptibility of poliovirus to wastewater treatments seems to be within an order of magnitude of other waterborne viruses, and controllable with them. However, wastewater treatment, including chlorination as currently practiced, reduces but does not eliminate enteric viruses. Thorough and consistent breakpoint chlorination could, however, be expected to reduce viruses very effectively.

Other picornaviruses resemble poliovirus in varying degrees. Some of the higher numbered echoviruses (rhinoviruses) are associated with the common cold, are more pH-sensitive and have not often been reported in water. The coxsackie and lower-numbered echoviruses are quite similar to poliovirus in physical properties and distribution in the environment; their behavior more or less resembles that of polioviruses in water processing. Like poliomyelitis, infection with these agents is far more widespread than disease. Unlike poliomyelitis, the acute diseases appear to be reversible, and to affect targets other than the nervous system, such as skeletal, muscles, heart, liver, pancreas, etc. While immunization might be mobilized to control these diseases, the reversibility of disease and antigenic multiplicity make a vaccine unlikely. Society generally accepts the diseases, and the epidemics are not recognized as waterborne. Recently, however, there have been suggestions for a role of coxsackieviral infections in chronic conditions such as chronic heart disease, diabetes, and mongolism. Should such etiology be established, there would be considerable impetus for their total elimination from water (5).

Poliovirus and the other viruses are little affected by primary treatment. The level is reduced up to 90% by secondary treatment such as biological activated sludge or sewage lagoons.

Disinfection by breakpoint chlorination, as is in Proposed Methods of Wastewater Treatment, should be effective (6).

Infectious hepatitis is the only viral infection generally acknowledged to be waterborne in epidemics. While virtually every viral group has at least some member that can cause liver inflammation, there remains a separate entity of viral hepatitis for which the etiologic agents have not been thoroughly established. Methods of cultivating the virus in the laboratory have yet to be established and most available data have come from epidemiologic studies or experiments with human volunteers. The limited information suggests that infectivity can survive most wastewater treatment procedures, and that infection is more prevalent than disease (7). In view of the past, optimism seems foolhardy, but recent information on Australia antigen suggests a needed breakthrough. Additional research, particularly on the behavior of Australia antigen in water, is urgently needed.

Adenoviruses have been isolated from water supplies, wastewater, and recreational water. They are known to cause respiratory and eye infections but they have also been isolated from cases of hepatitis. They are of special interest because several types are oncogenic in animals; human oncogenicity has not yet been demonstrated.

Reoviruses were originally included with the echoviruses, but were established as a separate group when a marked difference in size was discovered. Reoviruses also occur in animals other than man. Their contribution to human disease is not fully known. In addition to causing enteric diseases, experimentally they have been shown to affect the heart and to produce birth defects. While they have been isolated from sewage and may not be eliminated completely by conventional treatment methods as currently practiced, the proposed alternative systems for wastewater management would appear to be effective against these agents.

Other viruses, such as para-influenza, have been reported in water. Their survival time in water may be short enough that transit time through the water handling system by itself would render them inactive. Other viruses, such as arboviruses (arthropod-borne), would only be indirect problems if the water-handling strategies affected their potential vectors.

There remains a collection of agents recognized only relatively recently - the so called "slow viruses". These agents are resistant to heat, formalin, freezing and thawing, ultraviolet light, and ionizing radiation. They appear to be smaller than currently known viruses, induce no immune response in the infected host, have extremely long incubation periods, and lead to a slow inexorable progressive disease. Consideration of the slow viruses, even with the low level of present information, is justified not by established significance in human disease, but as an example of the extreme limit of stability of infectivity among the various biological pathogens. It is incumbent on planners and investigators, knowing that such agents exist, to delineate their potential hazard, as a class, before increasing intensity of use and recycling of water create future health problems. What is known about some slow viruses suggests that they are a very different type of infectious agent, perhaps subviral in nature. The resistance of these agents to chemical and physical treatments is far greater than even that of infectious hepatitis virus. It is for this reason that they merit consideration at this time even though their true prevalence and contribution to human diseases remain to be demonstrated. The human examples currently known are exotic, but relationship to more common, devastating chronic diseases of man has been hypothesized. Little information exists to predict behavior of this type of infectious principle in wastewater treatment systems.

In view of the increased use, and more importantly reuse, of water, it is now acknowledged that seemingly minor factors

neglected in the past and present, can no longer be ignored. The rare or weak exposure will become more common or stronger and hence more hazardous. In both financial and humane terms chronic diseases are significant burdens to the individual and to society. Therefore, considerable effort and expense are justified for the elimination of pathogenic viruses from water. It is now recognized that the occurrence of any infectious virus in water must be considered hazardous.

C. Potential chemical hazards

Chemical agents which may be found in wastewater can pose both direct and indirect hazards to the health of individuals who may become exposed to these substances. Some of these materials can also produce subacute or chronic disease, which may not become evident until a period several years from initial exposure. Other substances, meanwhile, may be capable of producing immediate and evident toxic effects upon exposure.

Included in the large number of materials which may produce direct toxic effects following exposure to certain types of wastewater are the heavy metals. Elements of toxicologic concern in wastewater include lead, arsenic, barium, copper, cadmium, chromium, selenium, and zinc. Cooper (1) cites several instances of increasing awareness of disease caused by cadmium. Included in these examples is a deadly bonewasting disease called itai-itai, which is transmitted by cadmium found in wastewater. While a wide range of other diseases are implicated as being caused by varying levels of cadmium concentration, further studies are providing an increasing awareness of other potential pathological effects of this element.

The carcinogenecity of trace quantities of polyaromatic hydrocarbons from wastewater has been reported. Nitrites, which, when reacting with secondary amines to cause nitrosamines, have been labeled as a "newly identified environmental carcinogen" (1).

Since it is known that infants can convert nitrates into nitrites in their intestine, the presence of high levels of nitrates in water could present additional hygienic complications. This intestinal reduction of nitrates to nitrites is known to be involved in the formation of methemoglobin, which causes an acute illness resulting from the inability of hemoglobin to transport oxygen to the tissues (1).

The toxicity of short-chained alkylmetallic compounds is reported to be extremely high because of the prolonged retention of these substances in nervous tissue, due to their lipid solubility. Some of these compounds which have caused fatal human neuropathic disorders include methylmercury, ethylmercury, tetraethyllead, tetramethyllead, triethyltin, and cyclopentadienyl manganese (1). The methylation of mercury by certain bacteria and the biomagnification of these substances in the aquatic environment has increased the concern that other substances may undergo similar transformations. The biomagnification of insecticides, including the organochlorines, organophosphates, and the carbamates, has further increased the concern of hazards to human health because of man's position at the apex of the aquatic food chain (1).

In short, the effects of many toxicants are not well documented. Hence, in many cases, the standards which exist for these substances are somewhat arbitrary, since the clinical effects of very low levels of these substances may not be known. Some of these substances become more toxic with another material than when found alone. Others become more toxic through the action of certain biological agents or by becoming highly concentrated through biomagnification processes. As industrialization increases, additional materials of unknown human effect will be created, and the problems of reducing these potential human hygienic hazards will become more complicated.

D. Disinfection

The practice of breakpoint chlorination has long been used to generate a free chlorine residual in potable water supplies. Achievement of a free chlorine residual requires the application of sufficient chlorine to satisfy the chlorine-demanding components of the water. In the case of potable water, this chlorine demand is exerted mainly by the ammonium ion, which reacts with hypochlorous acid (HOCl), a hydrolysis product of chlorine (Cl_2). When chlorine is applied in an approximate ratio of two moles chlorine to one mole of ammonia, a substantially complete oxidation-reduction reaction takes place. The completion of this reaction is called the breakpoint and any additional applied chlorine exists mainly in the form of hypochlorous acid or hypochlorite ion and is called the free chlorine residual. The ammonia reacts successively with hypochlorous acid to form mono-, di-, and trichloramines.

In the case of wastewater, the primary purpose of chlorination is the same as for potable waters. Chlorination is practiced to disinfect the waters and protect the human population from bacteria, viruses and protozoans which may be pathogenic. By its nature, however, wastewater is much more complicated in composition and exerts a much greater chlorine demand than potable water. Wastewater commonly contains 20 - 50 mg/l of ammonia and 10 - 35 mg/l of organic nitrogen (8). In order to achieve a free chlorine residual, up to 150 mg/l of chlorine may be needed for settled sewage and 25 - 60 mg/l for trickling filter (secondary) effluents (9).

Breakpoint chlorination of wastewater has not been widely practiced, mainly because of the cost of chlorine necessary to do so. Subchlorination, the application of sufficient chlorine to provide a combined residual made of chloramines has been sufficient to meet most disinfection requirements in sewage treatment plant

operation. Feng (10) has stated that breakpoint chlorination is less effective in wastewater disinfection than subchlorination. Other work by Kott (6), however, indicates that the seemingly lower disinfecting power of free chlorine may be an artifact as increased dosages of chlorine caused further break-up of organic matter, releasing the occluded coliforms. It is well known that clumping of bacteria (as well as viruses and cysts) tends to protect the inner cells from chemical disinfectants. The process of breakpoint chlorination may be giving more complete disinfection as a result.

The disinfecting power of hypochlorous acid (HOCl) is approximately 25 - 100 times that of monochloramine (NH_2Cl) (11). Monochloramine, in turn, is more lethally active than di- and trichloramines and the chlorinated products of other nitrogen-containing components of sewage (amino acids, polypeptides, proteins) (10). Many of these compounds exhibit practically no germicidal activity. It is reasonable to expect that as in the practice of potable water treatment, breakpoint chlorination will probably result in more complete disinfection of wastewater than the current practice of subchlorination. This would be especially true for viruses and cysts of Entamoeba histolytica, which are much more effectively attacked by free chlorine than chlorine in a combined form (13).

There are several questions which must be considered in breakpoint chlorination of sewage, however. Although more complete disinfection could be a beneficial result, one drawback may be the increased chemical costs for chlorine. Another problem could arise with the pH of the chlorinated effluent. Chlorine gas reacts with water to form hypochlorous and hydrochloric acid.

$$Cl_2 + H_2O \rightleftharpoons HOCl + H^+ + Cl^-$$

In cases where large amounts of chlorine must be added to reach the breakpoint, the low pH of the effluent could present serious problems to plant equipment as well as to the receiving waters (9).

There may also be problems with trichloramine (NCl_3) in waters which have been chlorinated to the breakpoint (13). Especially in the presence of urea (a constituent of human waste), the trichloramine can give rise to taste and odor problems in the treated water (14). But the proposed use of activated carbon following this stage of chlorination should substantially reduce or eliminate many of these problems.

While chlorine has traditionally been the disinfection method of choice by most wastewater treatment plants in this country, alternative methods have been investigated. The use of ozone, for example, has drawn increasing attention as a method of wastewater disinfection.

But the major problem with the use of ozone for disinfection seems to be the paucity of information available to American scientists and engineers. There are several publications in press at this time which should help remedy this situation (15). Most of the early work done on ozone as a disinfectant came from Europe and the results were not readily available here.

The consensus of opinion here has been that ozone is more expensive than chlorine and that at the pH of most waters it does not provide a lethal residual activity. The disinfecting behavior is called "all or none". Below a critical concentration (depending on temperature, pH, organic load) ozone possesses essentially no disinfecting power but accomplishes substantially complete disinfection above that concentration. European studies, as reported by Stumm (16), indicate that ozone has a higher reaction rate with microorganisms and organics than does chlorine. Like chlorine, disinfection with ozone is a function of contact time, concentration

of disinfectant, temperature and pH. The contact time necessary for 99% kill of E. coli in water is seven times greater for hypochlorous acid than for an equivalent amount of ozone (16). Ozone is also reported to destroy 99% of the cysts of E. histolytic within 1 - 3 minutes at an application of 0.5 - 1.0 mg/l. Inactivation of poliovirus is reported at an ozone level of 0.15 mg/l (16).

Although the general opinion seems to be that ozone is much more expensive than chlorine, this does not appear to be the case today. Modern ozone generating equipment can lower the cost of ozone for disinfecting below that for chlorine (17). Such equipment generates ozone right at the site of disinfection. Air is drawn through a series of filtering, cooling, and dessicating steps then passed through an electric arc which generates the ozone. The ozonated air and water are then brought into contact for about ten minutes to achieve disinfection.

The question of safety of chlorine versus ozone is a complicated one. Gaseous chlorine is less toxic, with a threshold odor concentration of 3.5 ppm (by volume). Chlorine concentrations above 30 ppm induce coughing and exposures to 40 - 60 ppm for 30 minutes can cause tissue damage. The gas is rapidly fatal above 1000 ppm (14). Ozone, however, is much more toxic (0 - 1 ppm threshold level) and gives no warning irritation below this level (17). A partially equalizing factor may be that ozone can be generated at the point of use while chlorine requires more handling, presenting greater opportunity for accidental exposure.

According to Berg (18), the chlorination of ammonia-containing effluents generally produces chloramines before the breakpoint is reached. These chloramines are toxic to fish and are also slow disinfectants. Ozone, on the other hand, does not react with ammonia, although it may react with other substances. Wastewater which has large amounts of ammonia may also be treated with iodine,

to avoid the formation of chloramines. In the absence of reducing agents, iodine may be useful in the disinfection of wastewater treated by physical-chemical methods. While elemental iodine is a slower virucide than hypochlorous acid, studies have shown that it will not be toxic to man at concentrations required to disinfect water (17). The effectiveness of bromine as a wastewater disinfectant is still under study. Under certain conditions, ultraviolet radiation may have some application as a virucide. Although gamma irradiation is a potent virucide, there is presently no practical means of employing it as a disinfectant for wastewater (17).

III. Potential Hygienic Impacts on Affected Streams Relative to Present Residual Levels and Designated Uses

A. Designated uses

The impact of an effluent, of any quality, upon a stream cannot be effectively evaluated without consideration of existing stream characteristics and intended uses. As is illustrated in Table I, the waters of concern in this study are protected for a wide range of uses. Of primary hygienic concern, however, are those waters which are designated for use as domestic drinking water supply, total body contact, and partial body contact. Standards for each of these uses have been established by the Michigan Water Resources Commission

B. Levels of residuals

Existing water quality

As was indicated in the Appendices for the Feasibility Study of Alternatives for Managing Wastewater for Southeastern Michigan (19), areas of Lake St. Clair now suffer from degradation, and the contamination from the Clinton River sometimes contaminates the bathing area of Metropolitan Beach. During periods of rainfall, the Detroit River suffers severe contamination from stormwater and

TABLE I

WATER USES TO BE PROTECTED BY
WATER QUALITY STANDARDS
SOUTHEASTERN MICHIGAN (20)

Water uses to be protected by water quality standards are for the areas drained by the Belle, Pine, Clinton, Rouge, Huron, and Raisin rivers and the minor tributaries to Lake St. Clair, the Detroit River and Lake Erie.

A. Water Supply
1. All existing public water supply intakes will be protected for Domestic Water Supply at the point of intake.
2. All public waters will be protected for Industrial Water Supply.

B. Recreation
1. All natural lakes will be protected for Total Body Contact. Where an existing public swimming beach is located on an impoundment of a public stream, the impoundment shall be protected for Total Body Contact.
2. All public waters will be protected for Partial Body Contact, except those protected for Commercial and Other.

C. Fish, Wildlife and Other Aquatic Life

All waters managed and naturally suitable for trout as designated by the Michigan Department of Conservation will be protected for Intolerant Fish, cold-water species.

All waters naturally suited shall be protected for Intolerant Fish, warm-water species, except those protected for Commercial and Other.

The River Raisin, from the first dam above the mouth to the west city limits of the City of Monroe, shall be protected for Tolerant Fish.

The South Branch of the River Raisin, from the City of Adrian to the confluence of the main river, shall be protected for Tolerant Fish.

D. Agricultural

All public waters will be protected for Agricultural Uses, except those protected for Commercial and Other.

E. Commercial and Other

The River Raisin, from the mouth to the first dam above the mouth, shall be protected for Commercial and Other.

Willow Creek, tributary to the Huron River, shall be protected for Commercial and Other.

The Rouge River from the mouth to the Michigan Avenue Bridge in the City of Dearborn shall be protected for Commercial and Other.

Dissolved oxygen requirements for Fish, Wildlife and Other Aquatic Life - Intolerant Fish, warm-water species will apply during the months of March, April and May.

The above designated uses are not intended to be applicable to drainage ditches. However, Act 245 of the Public Acts of 1929, as amended, prohibits unlawful pollution of all waters of the State of Michigan.

It has been and continues to be the policy of the Water Resources Commission to abate existing pollution and prevent the occurrence of future pollution of all waters of the state including drainage ditches.

raw sewage. Downstream from the Rouge River, the quality of water in the Detroit River has concentrations of toxic materials and coliform bacteria which indicate a possible health hazard. At the mouth of the Raisin River and at Sterling State Park, the water is considered unsafe for human recreation. Existing water quality in the other major streams within the study area are not always within the limits of acceptable standards for their designated uses, even at sites above major treatment plant effluents (See Table II).

Proposed water quality

Each of the wastewater and stormwater treatment alternatives as proposed by the Corps of Engineers can be expected to significantly improve or eliminate many of the existing problems, such as those mentioned above, from areas which are to be included as part of the service area. The proposed drainage of both sanitary and stormwater sewage from the service area into plants, which are expected to discharge no critical pollutants, should substantially improve the overall water quality in both the rivers which will collect the direct discharge and the larger receiving bodies of water, such as Lake St. Clair and Lake Erie. While dilution occurring from the discharge of the wastewater effluent into the streams may improve the overall water quality, the benefits which this will afford on specific hygienic aspects of the stream are questionable. For example, it has been reported that, even with the complete elimination of new discharges of mercury into the waterways, existing deposits in sediments will continue to yield the highly toxic methyl mercury for decades (22).

It should also be realized that, while any contaminants which are generated in the service area of the proposed wastewater management system will be either reduced significantly or eliminated, this system will not improve conditions which are created upstream from or outside of the proposed service area. Upstream residuals,

TABLE II

SPECIFIC WATER QUALITY DATA SELECTED FROM LOCATIONS UPSTREAM FROM POINTS OF PROPOSED MAJOR TREATMENT (21)

River Location	Total Coliform*	Fecal Coliform*	D.O.**	B.O.D.**	Susp. Solids**	NO_3-N**	Cl**	NH_3-N**	O-PO_4**
Upper River Rouge - at U.S. 24 Bridge (Redford Twp.) 8/17/72	230,000	6,000	4.2	6.0	26	0.80	64	0.13	0.07
River Raisin at Sharon Valley Rd. Bridge (Sharon Twp.) 9/19/72	26,000	150	5.4	1.6	18	0.14	15	0.03	0.01
River Rouge at Fenkell Ave. Bridge (City of Detroit) 8/17/72	68,000	4,800	3.0	7.8	364	0.80	52	0.15	0.110
Huron River at N. Territorial Rd. Bridge (Dexter Twp.) 8/7/67	2,800	<100	6.2	3.2	15	0.0	22	0.0	0.0
Saline River at Dell Rd. Bridge (Saline Twp.) 12/18/67	10,000	400	10.8	1.6	14	1.90	18	0.20	0.50

* Per 100ml
** mg/1

such as those existing levels illustrated in Table II, must be substantially reduced if one is to assume that the water quality of the streams will present no health problems upon the public. While stratigically located physical-chemical treatment plants have been proposed to serve small upstream communities in an effort to reduce many of these residuals, high projected population growths in these areas could make this residual control less effective. That is, increases in the population upstream from a proposed service area might serve as an upstream source of undesirable contaminants. The population in the Upper Raisin River, for example, is projected to climb from approximately 70,600 at the present to almost 155,500 by the year 2020 (19).

In short, while the effectiveness of a proposed system of wastewater management should be appreciated, some of its limitations must be realized. That is, as long as there are areas nearby which are not served by this, or any other system, it should not be implied to the public that this system will protect them from all potential public health problems.

IV. Assessment of Some Hygienic Considerations for Alternative Wastewater Management Systems

A. Advanced wastewater treatment system (total)

1. Reduction of potentially hazardous biological agents

The advanced wastewater treatment, as proposed, with breakpoint chlorination is considered to be an extremely efficient method of removing a wide variety of potentially infectious agents. While the reduction of coliform organisms is well documented and need not be discussed in detail here, the removal of viruses from wastewater has recently been given increased attention.

Traditional advanced biological treatment has been demonstrated to be highly efficient in reducing the concentrations of viruses present in the effluent (23). Clarke (24,25) has reported

that this form of treatment is capable of yielding an effluent from which 90% to 98% of the viruses have been removed. While this high level of viral reduction can be obtained, it must be emphasized that the conventional practice of chlorination has, on occasion, permitted the release of significant levels of infectious virus (5). It should be further emphasized that the minimum infectious viral dose is that level which can be detected by any other means. That is, unless 100% removal of all viruses is maintained with the treatment process, a potential hazard of human infection will exist. While the discharge of viruses into the water will eventually result in their destruction, in the absence of the acquisition of a suitable host, their survival time varies with the water purity and temperature. It is a paradox that the overall improvement of water quality could have the effect of prolonging the survival of enteric viruses. Both extremes of gross water pollution or high water purity increase enteric viral survival times (26).

An advanced wastewater system of biological coupled with physical-chemical treatments can be expected to achieve high efficiency in the removal of infectious agents prior to chlorine application. Coagulation has been observed to be highly efficient in the removal of viruses from water. 25 mg/l of alum in raw river water has been reported to reduce coxsackieviruses by 95 - 99%. The use of $FeCl_3$ is reported to have a similar efficiency (27). Robeck *et al*. (28) reported that processes of flocculation and settling may be expected to remove 95 to 99 per cent of virus from water. For efficient virus removal from wastewater the coagulant dosage must be high enough to insure good floc for adequate turbidity reduction (29). The removal of viruses by flocculation appears to result from a coagulant-cation-virus complex which aggregates and settles out (30). The expected increase in pH of the wastewater in the proposed system of advanced wastewater treatment can

also aid in the reduction of viruses. The destruction of poliovirus, for instance, appears to increase very rapidly with a pH above 10 (30). In practice, the Lake Tahoe system of advanced wastewater treatment has demonstrated a virus and total coliform removal of 99 per cent from the effluent (31).

While the removal of infectious agents throughout the system may be highly efficient, a critical aspect of this and other forms of wastewater treatment is the efficiency of the disinfection measures (33). While coliform organisms are often used as indicators of the thoroughness of disinfection, it must be remembered that these indicators do not always furnish accurate information on all possible pathogens. For instance, Greenberg and Kupka (2) discussed the findings of Jensen that coliform organisms are more sensitive to disinfection than are tubercule bacilli. With this in mind, a thorough evaluation of the reliability of coliform indicators might be considered. Disinfection must be relied upon heavily with tubercule bacilli since biological treatment has not been reported to significantly inactivate these organisms. As has been indicated, tuberculosis bacteria have been isolated from both domestic and industrial wastes (2).

A large variety of micro-metazoan parasites merit consideration since their successful transmission often requires a fecal-oral route. The efficiency of removal of many of these organisms is quite variable. Efficiencies of between 20% and 100% have been obtained by the use of a variety of activated sludge parameters for the removal of tapeworm ova, amoebic cysts, hookworm ova, and aquatic schistosomes (1). Kabler (32) reports that processes of chemical flocculation and sedimentation appear to be the most effective measures for removing parasitic ova from wastewater.

Vectors do not appear to present a major health threat in the proposed system as long as basic hygienic rules and health standards are met.

2. Reduction of potentially hazardous chemical agents

Assuming that this system of advanced biological treatment consistently meets the standards as set by the Army Corps of Engineers for certain critical effluents, it may be necessary to consider a wide variety of toxicants which may exert subacute or long-term carcinogenic effects but which are not successfully removed by advanced biological treatment. In 1967, for example, a study showed that activated sludge from treatment plants in Nashville, Tennessee was unable to remove, by oxidative mechanisms and normal retention time, 27 substances known to be carcinogenic to laboratory animals (34).

The effluent from biological treatment plants are likely to contain some concentrations of many metals as well as certain hygienically significant non-metals and persistent compounds. Linstedt *et al*. (35) have found that such processes in advanced wastewater treatment as lime coagulation and settling, sand filtration, activated carbon adsorption, and a cation-anion exchange sequence were very effective in reducing the levels of cadmium, chromium, selenium, and silver in the secondary effluent. They further indicate that the process of lime coagulation-settling may produce effective separation of cationic-form trace elements which were studied. These investigators also demonstrated that activated carbon effectively retained trace quantities of silver, cadmium, and chromium from wastewater.

It is further concluded (35) that the processes of carbon adsorption, coagulation, and ion exchange may remove, along with certain trace metals, organics, suspended solids, and major inorganic ions. In light of present-day knowledge, the predicted concentrations of those substances known to be toxic at relatively low levels will not be sufficient to have immediate hygienic impact on bathers, but may be in excess of those levels which cause excessive concentrations in fish and other foods of aquatic origin.

In addition, crops grown on land which is irrigated with water taken directly from streams or lakes may also contain elevated levels of these substances, since evaporation of water from these plants may permit these materials to become more concentrated. There is presently no indication that this introduction of trace substances into the food supply of man constitutes a serious potential health hazard but, by analogy with mercury, which was not considered so hazardous a few years ago, it is apparent that our knowledge in this area is extremely limited and inadequate for assessing the impact on health fifty years hence.

3. Consideration of other factors

While discussing the possible health impacts of a wastewater disposal system on the public, one cannot ignore the possible health hazards which the employees of these treatment plants are obliged to face. The potential infectious diseases which may be transmitted include all of those which are possessed by persons in the wastewater donating community and which are excreted into the sewage. Several diseases have been reported to have been contracted by workers while employed at a wastewater treatment plant (3). Napolitant and Rowe found that these activated sludge plants put approximately ten times as many coliforms into the air as do high-rate trickling filters. In an activated sludge plant, the aeration tanks emit three times as many organisms as any other unit in the plant.

A study of airborne bacteria over activated sludge aeration tanks was done by Randall and Ledbetter (37). They concluded that the bacterial population in air over activated sludge plants increased significantly, from a total of approximately eight organisms per cubic foot upwind to 1170 organisms per cubic foot downwind. They found that bacteria of the family Enterobactereaceae made up 19% of the total bacteria emitted and that about 10.5% of the total were genera which are potential respiratory pathogens

(*Klebsiella*, *Proteus*, *Aerobacter*). Studies downwind of the aeration tank indicate that the capsule-forming bacteria such as *Klebsiella* and *Aerobacter* are better suited to airborne survival than the coliform types.

The sludge which is generated by the proposed method of advanced wastewater treatment may reasonably be expected to contain most of the potentially pathogenic agents and hazardous chemicals that occur in the influent wastewater. The nature of the sludge will vary throughout the treatment system. The untreated primary sludge is an area of major hygienic concern, with the secondary sludge expected to pose fewer potential problems.

Although general sludge disposal considerations will be reviewed later in this report, some specific observations relative to this particular wastewater treatment system are in order here. It is reasonable to assume that the disposal of sludge which has been subjected to 250 to 450 degrees F. and 100 to 150 psi prior to landfill disposal will exert almost no biological problems. The sludge should be almost completely disinfected, providing that sufficient mixing enables thorough heat contact. The lime sludge, as generated following two stages of secondary treatment, may be expected to be relatively noninfectious and to have had most toxic metals removed prior to this stage. The high pH of 10 to 10.5 can be expected to aid in the disinfection of the sludge. Landfill disposal of this lime sludge may be expected to pose no significant health problems. The sludge as obtained from primary and secondary clarification stages should contain most of the infectious agents and potentially hazardous chemicals. With proper precautions, including disposal sites which are not at depths near the groundwater table, sanitary landfill disposal may be a relatively safe method of disposing of this sludge.

Specific considerations of ash disposal, following sludge incineration, will be discussed later in this report.

B. Land treatment system (total)

1. Reduction of potentially hazardous biological agents

The spray irrigation of pretreated chlorinated effluent can be expected to provide a marked reduction in potentially infectious agents found in the effluent. The soil mantle, under proper soil conditions, can be expected to efficiently remove or inactivate most microbial pathogens (1). While the effluent may be considered to be relatively pathogen-free, specific hygienic considerations must be directed to the site of the land disposal. Soil type appears to be more important in the reduction of coliform organisms than the rate of hydraulic infiltration. The passage of wastewater through 5 to 10 feet of fine soil should elminate microbial contamination before the effluent reaches the groundwater (38). The removal of viruses from the soil is accomplished primarily by adsorption. This adsorption of viruses by soils is affected greatly by the pH of the water-soil system. Due to the amphoteric nature of the virion protein shell, the effectiveness of virus removal by the soil is decreased as the pH is increased. This is caused by increased ionization of the carboxyl groups of the virus protein and by the increased negative charge of the soil. At a pH below 7.0 - 7.5, however, the removal of viruses by soil is fairly rapid and effective. Increases in the cation concentration of the wastewater prior to soil infiltration will help neutralize the electrostatic effect on either the virion or the soil particles. This would result in increases in the capacity of the soil to adsorb viruses (39).

It has, however, been reported by Wallis and Melnick (40) that high concentrations of Mg^{++} enhance the susceptibility of cells to infection by poliovirus. They indicate that the release of polio viruses from cells may be aided by the presence of magnesium ions. These investigators (41) then indicate that, in the presence of ions such as Mg^{++}, Ca^{++}, and Na^{+}, certain enteroviruses, such

as polio, ECHO, and Coxsackie viruses experience stabilization at temperatures above 50°C. The activity of 25 ECHO viruses and 7 Coxsackie viruses, after heating in M $MgCl_2$ or $CaCl_2$, was not reduced significantly. A partial loss of infectivity when these viruses were heated with 2M NaCl was found only in Coxsackie A9 and B4. Puck et al. (42) indicate that Mg^{++} can activate an inert mixture of virus and host cells in distilled water at a rate more rapid than the 20-second resolving time of their experimental procedure.

Cations in general have been reported to protect poliovirus from thermal inactivation. Magnesium ions have been found most effective in this protection and studies indicate that this ion may stabilized other RNA-containing viruses (43). Present evidence indicates, however, that virus movement through soils under saturated conditions should present no hazard to groundwater supplies (39).

In an environment, such as that under constant or periodic spray irrigation of sewage the often ignored threat of fungal infections can not be overlooked. Fungi which are capable of causing very severe human disease have been isolated from sewage (3). Fungi pose an unknown problem, in most cases, since these organisms have often been ignored when studying possible waterborne disease transmission. Areas which receive intermittent spray irrigation, if permitted to dry, could make wind transmission of potentially dangerous fungal spores a very real problem. Many of the fungal diseases, such as Blastomyces dermitiditis, which have an unknown natural habitat and could find an environment of this nature very suitable for propagation.

Care must be taken to assure that any vegetation grown with the spray irrigated wastewater is uncontaminated prior to ingestion by livestock. Cases of tuberculosis transmission to pigs which had been fed with grasses which had been irrigated with untreated sewage

have been reported (2). In addition, there is an increased danger of viable ova deposition on forage through the irrigation of wastewater and by the subsequent ingestion of the plants by farm animals. Cases of Cystericercus bovis in beef cattle have been described as being transmitted through sewage irrigated cattle forage (44).

Adequate disinfection, such as breakpoint chlorination or thorough ozonation, prior to land application would substantially reduce the possible diseases which might result from infectious agents. It is important to consider that, while a particular method of disinfection may reduce or eliminate the presence of coliform bacteria in the wastewater, certain infectious agents such as viruses or Mycobacterium sp., are more resistant to chlorination than these indicator organisms. A spray irrigation system without breakpoint chlorination, as is proposed, should effectively reduce or eliminate the threat of infection via specific biological agents found in the effluent.

However, more research is needed on the possible aerosol transmission of infectious agents, including viruses and fungi, from the proposed aeration lagoons. Evidence has been cited (37) which indicates that the increase of bacterial indicators, and consequently the possible increase of other infectious agents, is significant in the vicinity of activated sludge aeration tanks. More thorough documentation of the actual dispersal of infectious agents by the proposed aeration lagoons would be a great asset in determining their true hygienic impact.

Aside from the very real problem of parasitic infections, precautions must be taken in an effort to prevent the rapid increase in vectors. Organisms of concern include mechanical vectors, such as flies or rats, and biological vectors, such as mosquitoes. Potential mosquito breeding sites in wet areas could provide a direct aggravation, as biting insects, and an indirect biologic threat, as vectors of malaria and arboviruses. Both malaria and

yellow fever were once indigenous to the study area and the return of significant areas of land to an ecologically pristine state should not be allowed to reinstitute the hazard. Proper effluent application rates, which would permit maximum soil infiltration and minimize ponding, could help reduce the multiplication of vectors and fungi in spray irrigated areas.

2. Reduction of potentially hazardous chemical agents

While achieving the Corps' standards of "no discharge" of critical pollutants into the streams, a wide variety of other hygienic considerations must be investigated. With continual application of wastewater containing a wide variety of toxic metals or other persistent chemicals, both ecological and hygienic impacts may be felt. Since ecological impacts will be dealt with elsewhere, we will concern ourselves with the possible hygienic effects.

According to the Michigan State University Institute of Water Research (45) the discharge of arsenic, cadmium, cobalt, copper, iron, manganese, nickel, and zinc at levels as proposed should present no major health risks. They further indicate that, while the toxicity of chromium is not well understood, some potential risks might be associated with mercury, cadmium, boron, and lead.

Further consideration might be given to such elements as selenium and molybdenum, which have been shown to be taken up and concentrated by plants to levels which are toxic to animals (46). While work on radio-nuclides has shown up to 95% removal in laboratory studies on soil columns, it was further demonstrated that certain isotopes were not removed (1). The accumulation of radioactive materials could, under certain conditions, pose a problem. This, however, merits further investigation. In an effort to minimize the surface emission of odors, anaerobic conditions should not be permitted to persist (44). The removal of heavy metals by the soil is dependent upon soil texture (38). Spray

irrigated plants may take up ions through their leaves. Subsequent evaporation of water from these plants leaves a high residual concentration of the ion, although the initial levels may have been very low. While these detrimental effects have been shown on certain plants with chlorides, it is probable that serious problems would not be created on the proposed crops to be irrigated under this system (46).

The most significant component of the groundwater dissolved solids load may be the nitrate ion. USPHS Drinking Water Standards specify that the total nitrate plus nitrite level must not exceed 10 mg/l as N. This level has been determined to be the upper limit above which there is a risk of methemaglobinemia in infants and children (47,48). The nitrate problem is multifaceted. Studies done on spray irrigation of sewage at Pennsylvania State University indicate that nitrate is one of the most mobile ions in sewage when sprayed onto soil (49). At high levels of wastewater application, the groundwater below sprayed areas may show increased nitrate levels. In some wastewater irrigation studies, these levels have exceeded the 10 mg/l USPHS standard (50).

While it has been reported that nitrate levels above the USPHS of 10 mg/liter of NO_3-N may be found in recharged groundwater following the land application of sewage (38), it has been reported that, under proper conditions, the proposed method of wastewater irrigation in Southeastern Michigan may be expected to yield an effluent of approximately 3 mg/l (51). Winton et al. (52) suggest that the formation of elevated levels of methemoglobin in infants under three months of age may result from daily exposure to nitrate levels in excess of 10 mg/kg. The levels of nitrates in the Corps of Engineers proposed effluent should not create any recognizable health problem from infant methemoglobinemia.

Natural chemical and biological processes which occur in the soil have been reported to offer good possibilities of municipal

wastewater reclamation without the hazards of elevated levels of eutrophication, if properly managed (55).

3. Consideration of special problems

a) Spray irrigation

The process of spray irrigation itself can be expected to produce special problems which are not inherent in the other proposed alternatives. Aerosols may be produced which may present both a biological and chemical health hazard to persons downwind from the point of application. Adams and Spendlove (54), for example, discuss an experiment performed by Schultze in 1943. He demonstrated the recovery of *Eschrichia coli* at varying distances downwind from a site where raw sewage was being used for purposes of spray irrigation. In further studies (54), the presence of *E. coli* from trickling filter plants has been demonstrated at distances between 600 yards and 0.5 miles downwind from the treatment plant.

The amount of aerosol formation by spray irrigation processes will be affected, to a large degree, by the type of nozzle used for wastewater application and by the spacing of these nozzles. Manufactured spray nozzles are designed to operate over a range of 5 - 130 psi, with increases in pressure generally proportional to increases in the formation of aerosols (5). Optimal nozzle design should be governed by efforts to minimize aerosols while providing an acceptable rate of wastewater application.

Despite the rapid dieoff of the indicator organism, *E. coli*, in aerosols it has been recovered at the above mentioned distances downwind. There is a need for the study of other bacteria, such as organisms of the encapsulated genus of *Klebsiella*, of which all of the known species are considered to be pathogens of the respiratory tract (38). There have been very few, if any, studies concerning the downwind recovery of viruses and fungi from sites of spray irrigation. A large number of viruses merit further

consideration, when it is realized that, along with having a very small infective dose, these organisms may travel long distances in aerosols before infecting the respiratory tract. Viruses such as influenze have been shown to travel considerable distances in aerosols before human infection. Sorber and Guter (55) cite a preliminary study which indicates that land spraying of chlorinated effluent resulted in about 1.5 times the number of viable airborne organisms as a trickling filter. While the water phase might be expected to act as a selecting media, restricting the airborne viruses to those that are found in water, recent studies show that aerosols from treatment plants contain respiratory rather than enteric bacteria (37).

In addition to the above biological consideration there is a wide range of chemical considerations which must be investigated regarding possible hygienically detrimental effects of spray irrigation. Hydrogen sulfide is the principle gas of concern and, although it is highly toxic, concentrations are not expected to approach levels causing toxic responses in downwind populations. This gas may, however, easily exceed the odor threshold and result in large scale odor problems among neighboring communities. Even though it may be true that hydrogen sulfide emissions are negligible throughout most of the year, certain periods during the winter months might be troublesome due to development of anaerobic conditions, conducive to hydrogen sulfide and methane formation by specific sulfur-reducing and methanogenic microorganisms.

Special attention must be given to wastewater treatment plant employees who may be exposed to contact with aerosols over an extended period. Potential infectious and non-infectious disease could become very real threats to the health of these employees because of this exposure.

Once again, it must be emphasized that the successful elimination of potentially infectious agents in the effluent is

almost directly related to the effectiveness of disinfection procedures. Current practices of chlorination do not consistently yield a pathogen-free effluent. Although, infectious agents may be present in aerosols formed by this system, there is need for further research on the transmission of viable fungi and viruses downwind from the treatment site.

b) Sludge disposal

The sludge generated by this alternative can be expected to contain essentially all of the potential pathogens and harmful chemicals contained in wastewater. The proposed method of disposal of this sludge, by plowing it into nearby land which contains underground drainage tile, may be effective.

Kudrna (56) cites Carlson and Mencies that cultivated farmland can easily handle up to 8095 lbs per acre of processed garbage or sewage sludge. In further studies, Cotton (57) found that accumulation of heavy metals in soil which had received either wastewater or sludge application for approximately 100 years was not apparent. Cotton further indicates that the wastes which had been applied had a record of high heavy metal content. Studies on the agricultural and environmental impacts of land application of digested sludge (58) showed that no nuisance or fly problems were created. This report further indicated that, from an aesthetic standpoint, furrow irrigation is the preferred method of application. It might be added that, in his chemical analysis of soil which had received lengthy sludge application, Cotton recorded 23,000 mg/l of total nitrogen from one plot of soil.

From a hygienic viewpoint, it is essential that the earth be plowed enough to prevent the contamination of streams from excessive runoff. A potential health hazard could exist if, during a substantial rainfall, the soil is unable to protect the sludge from runoff. Another health hazard might exist for the person responsible for driving the tractor which is used to plow the sludge.

His lengthy exposure to this material could pose an even greater health hazard than he might receive as an internal wastewater treatment plant employee. Remote or programmed control is technically feasible, and would reduce this hazard.

C. Physical-chemical wastewater treatment system (total)

1. Reduction of potentially hazardous biological agents

The proposed method of physical-chemical treatment of wastewater can be expected to reduce the level of potentially infectious agents and, following breakpoint chlorination, to yield an effluent which is virtually free of known pathogens. Much of the discussion concerning the physical-chemical aspects of the proposed system of advanced wastewater treatment is also applicable here. Processes of coagulation (27,29), flocculation (28,30), and settling are highly effective in the removal of viruses. In addition to levels of removal of infectious agents cited previously it is significant that up to 99.8 per cent virus removal has been reported in filtered lime-flocced effluent (59). Processes of coagulation may help produce an effluent with a pH which is high enough to effectively reduce viral concentrations throughout the system (30). While a high level of removal of potentially hazardous biological agents can be expected with this method of treatment, terminal disinfection is a necessary precaution for the production of a safe effluent. Disinfection by such methods as breakpoint chlorination or thorough ozonation remains an important safeguard against the possible release of these agents into the streams.

2. Reduction of potentially hazardous chemical agents

It has been reported that (31), while insufficient research has been done on the ability of physical-chemical wastewater treatment processes to remove toxic metals, most metallic ion concentrations should be reduced to at least trace levels. Although such metal ions as sodium, potassium, and boron, because of their solubility, will not be greatly affected by the proposed physical-

chemical process, cyanides, phenols, chlorinated hydrocarbons, and surfactants should be effectively removed.

Physical-chemical processes, when applied to the secondary effluent of a biological treatment plant, have shown very high efficiencies in the removal of heavy metals (35). These studies by Linstedt _et al_. (35) further indicate that cationic-form trace elements may be removed by lime coagulation-settling processes.

Treatment by physical-chemical means can therefore be considered effective in the removal of a wide variety of potentially dangerous chemicals. A wide variety of physical-chemical methods have been reported to be effective against contamination by mercury (22). The most feasible method of nitrogen removal with this method is breakpoint chlorination (60). But with this means of reducing nitrogen comes a significant chloride ion increase in the effluent.

The sludge, as generated by the proposed physical-chemical treatment process, can reasonably be expected to be almost completely free of potential pathogens. The pH of 11 to 11.5, which the sludge as removed by primary processes is expected to possess, should substantially reduce most potential pathogens to a level which would create very few hygienic problems. While problems associated with sludge incineration are discussed later in this report, landfill disposal should pose no major problems, provided precautions are taken, against possible groundwater contamination and against the possible accidental ingestion of the sludge by wildlife, for example.

D. Combined wastewater treatment system

This system of wastewater management can be expected to carry with it both the hazards and benefits of each of the above-mentioned alternatives. However, any public health problem which might be produced by land treatment, for example, may be reduced by being localized over a much smaller area.

E. Stormwater management system

Untreated storm sewer discharges from urban runoff have been found to contribute major amounts of contaminants to surface waters. Urban runoff, by its very nature, contains considerable amounts of undesirable matter such as animal droppings, fire and vehicular exhaust residue, de-icing compounds, pesticides, fertilizers, other chemical additives, decayed vegetation, sand, silt, and other unknown pollutants. In some instances, intentionally or unintentionally, sanitary or industrial effluents may gain access to stormwater discharges. These additions have been shown to greatly increase the levels of nutrients, solids, and bacterial indicators in stormwater (61).

Weibel et al. (62) cite several studies which indicate that high levels of potential pathogens and nutrients are discharged in urban storm runoff. They cite a study in Seattle by Sylvester where stormwater samplings contained up to 9.0 mg/l organic nitrogen, 2.80 mg/l nitrate nitrogen, and 1,400 µg/l of total phosphorus. They similarly report studies from Stockholm, Sweden and Pretoria, South Africa which revealed similar nutrient levels, and coliform levels at 200,000/100 ml and greater. Studies in Cincinnati have revealed similar results with coliform levels of up to 460,000/100 ml reported. Palmer (63) reported that, during a 1949 Detroit rainstorm, the MPN/100 ml coliform levels reached 930,000 at two separate collection times, for samples which were taken at a catch basin in the Detroit business district. Following a more recent Detroit study Palmer (64) indicated that "stormwater runoff from highly urbanized and highly populated areas is heavily polluted . . ." and that, again, very high coliform levels were found with the MPN test.

Studies performed in Traverse City, Michigan (61) during four major storms of July and August, 1972, indicate that storm sewers contribute highly significant levels of nutrients and indicator bacteria to Grand Traverse Bay. The total coliform

levels were found to fluctuate widely throughout the storm, but values of up to 2.81×10^6/100 ml were reported during peak flow periods.

While much of the stormwater monitoring of a hygienic nature has concerned itself with the contribution of indicator organisms and nutrients, the implication of viral contamination and the possible presence of chemical toxicants can not be ignored; there is a real need for further research in this area to determine the true hygienic impact of raw stormwater upon the health of the public.

The proposed methods for the treatment of stormwater, including physical-chemical treatment, physical-chemical treatment combined with limited land application, and total land application could all be considered to be effective means of treating urban runoff. These alternative systems are of course subject to the same hygienic considerations as are the similar systems for the treatment of wastewater. The two-stage lime clarification, filtration, carbon adsorption, and breakpoint chlorination of the physical-chemical system can be expected to yield a high quality effluent which would exert a minimal threat to the health of the public. Similarly, the proposed system of land disposal of stormwater, if carried out properly, can be expected to yield an effluent of insignificant threat to the regional population. Sludge considerations will be similar to those which were made regarding each alternative method of wastewater disposal and which follow as sludge disposal considerations. It must be cautioned that, although stormwater sludge is not of sanitary origin, the high levels of coliform and, by implication, other potentially pathogenic agents justify the careful and safe disposal of the accumulated sludge.

In light of present information, stormwater must be considered to be a significant health hazard to the public. Consequently, all

efforts should be made to protect the surrounding population from exposure to this material. The utilization of large storage lagoons should be made with this point in mind. Large lagoons may be affected by wind resulting in aerosol formation from wave action. Information cited earlier in this report (54) indicates that there may be cause for concern as the possible transmission of infectious agents from water via the airborne route. In the absence of more thorough information on possible disease transmission by this method, precautions should be taken in the construction of these storage sites to insure that the public is protected to the fullest practicable extent.

V. Sludge Disposal Considerations

A. Introduction

Many aspects of sludge disposal pose a wide range of potential public health problems. The methods of disposal in this study include both landfill disposal of ash following incineration and landfill disposal of dewatered sludge. Potential hygienic problems related to each of these methods will be considered separately.

The sludge constituents which are of major public health concern are the pathogenic organisms and toxic chemicals, both of which are almost always found in raw sewage. It has been reported that up to 90% of the pathogenic organisms, such as bacteria and macroscopic parasites may be found in sludge from primary sedimentation, while up to 99% of the wastewater viral particles may be removed by the activated sludge process. Generally, the same pathogenic organisms which are found to be present in wastewater influent can also be assumed to occur in raw sludge, although their numbers may be slightly diminished (1). Regarding health hazards of a non-infectious nature, most heavy metals of the influent eventually become sludge constituents. In general, clarification

can remove calcium, magnesium, strontium, barium, aluminum, trivalent chromium, manganese, iron, cobalt, nickel, and copper. Through adsorption in the process of lime precipitation, zinc, cadmium, arsenic, antimony, mercury, tin and lead may be removed. Such elements as mercury, cadmium, and zinc are strongly adsorbed on organic matter and may be expected in certain primary and secondary sludges. Persistent pesticides and, in particular, chlorinated hydrocarbons may be expected in the lipid fraction of sludge when these materials were present in the influent (1).

B. Some general considerations of landfill disposal of dewatered sludge

The use of dewatered sludge at landfill sites involves deposition of a material which includes concentrated forms of bacteria, viruses, parasitic ova, fungi, and non-infectious toxic materials. Infection by some of these agents has been reported in livestock which grazed upon sludge treated fields (2). While the proposed method of sludge disposal is distinct from land application of sludge for agricultural purposes, survival of agents, such as tuberculosis bacteria from digested and dried sludge from domestic sewage has been reported for periods up to five weeks(2). Sludge should be considered to be infectious material and preventive measures against its accidental ingestion by domestic or wild animals must be taken.

Under normal conditions and with adequate precaution against unnecessary exposure of workers or the public, the application of dewatered sludge directly to the land can be expected to have little hygienic impact. Regarding many of the potential hygienic problems which may be presented by this process, there is little available information. For example, since sludges may be relatively mercury-rich, significant release of methyl mercury is possible, but available data are inadequate. Regarding other significant biotransformations which might occur with many other persistent substances, data are almost non-existent. A great deal of further

research concerning fate of many of these substances is necessary for understanding their true environmental and hygienic impacts.

Again, it is necessary to consider the potential consumption by game animals of materials contaminated by this method of sludge disposal. It is highly likely that, unless definite precautionary measures are taken, these animals may become a threat to humans who may consume them.

Further consideration must be given to possible stream or groundwater contamination from natural runoff or increased ground seepage which could result from natural flooding.

C. Some general considerations of landfill disposal of ash following incineration

The incineration of sludges produces all of the potential and actual air pollution problems that face the power-producing industry, where coal or oil is burned; and the industrial incineration plants, which are used to destroy a wide spectrum of industrial wastes. It is convenient to recall that everything produced by the combustion of organic materials can be divided into two broad classes, namely particulate matter and gaseous matter. Particulate matter, by definition, consists of small particles which impede visibility, dirty surfaces, and are most noticeable as air pollutants. Gases consist of substances present as molecules dispersed in the air, and are normally invisible and unfilterable.

<u>Particulate matter</u>

The particulate matter resulting from the combustion of sludges is properly called fly ash, and consists of the smaller ash particles which become airborne by the combustion process. It is rich in minerals and usually consists of a mixture of oxides, silicates, or other salts dependent to some extent upon the nature of the mineral composition of the sludge. It may be quite appreciable in quantity, and if no steps are taken to reduce the amount of ash emitted, it will generally constitute a serious air

pollution problem. Excessive amounts of ash of all sizes are emitted, and are deposited on nearby surfaces, while the finest particles are carried for many miles as a visible plume. Without exception, all state and local air pollution codes would prohibit the emission of such quantities of ash, and demand that measures be taken to reduce the loadings considerably. In addition, with the provisions of the Clean Air Act, federal legislation will apply in any areas not covered by state or local legislation.

It is not difficult to reduce the amount of particulate matter emitted by an incinerator and several steps must be taken. First of all, good combustion must be promoted to completely prevent the formation of soot, or unburned particles. Normally, this is no problem, but if there were any tendency to produce black smoke, it would be necessary to improve combustion procedures or install after-burners to destroy the soot. Even though this is done, the ash particles will continue to be emitted, but should be grayish or light colored. Next, a primary collector of some kind should be part of the original installation for the purpose of removing much of the largest particles emitted by the combustion chamber, both economically and efficiently. Such primary collectors will not remove fine particles, however, hence the last piece of required apparatus is a high-efficiency dust collector of some kind. Generally speaking, so-called wet-collectors or scrubbers are favored because they are relatively trouble-free to operate, can deliver the required efficiency to meet today's air pollution codes, and in general, tend to be somewhat less expensive than certain other devices. The alternatives consist of so-called bag houses in which particles are removed by filtration through cloth bags, and electrostatic precipitators where high voltage electrical collectors remove the fine particles. All such devices should be investigated in relation to cost and other factors.

Present legislation requires, in essence, that the plume

emitted by a stack be almost invisible, that is, it must contain sufficiently few particles that it is possible to see through the plume without difficulty. It is highly probable that future air pollution regulations will be even more strict, and very likely demand that one day the plume be practically invisible. Although it is possible with the engineering devices just mentioned to achieve such a plume, the expense is likely to be considerable for removal of the last particles which are inevitably the finest particles, a costly, energy-consuming process.

Everything that has been stated thus far deals with particulate matter as such, without regard to its composition. There is concern over many of the metals emitted to the atmosphere, some of which are very likely to be found in the ash from burning sludge. The mixture actually encountered in any given sludge will be a function of the region that generated the sewage, and the nature of the input. Therefore while testing would be necessary to determine the presence and prevalence of various metals of interest, it is likely that any sludge will contain some of most of the so-called toxic or heavy metals. These include lead, cadmium, mercury chromium, nickel; along with larger amounts of the more common metals such as calcium, magnesium, silicon, iron, aluminum, etc. In general, there are not engineering measures specifically designed to remove one or more of these metals, they are completely removed by the engineering methods just discussed. A few metals such as nickel form gaseous compounds which could exist as such in the emissions from the combustion chamber, but most of them would be expected to be solids, and removed to the same extent that the particulate matter is removed from the flue gases. Because the standards for some of the metals are extremely stringent, however, stack emissions tests for some of the toxic metals listed, or for a light metal such as beryllium, may indicate that the small amount of particulate matter being emitted contains levels of toxic metals which merit more stringent control

procedures than might be thought necessary simply to control the total amount of emitted particulate matter. But in the light of all such considerations, it would be highly desirable for extensive studies to be performed on incinerating units already in existence, or on pilot models where existing incinerators might not be adequate as models.

Gaseous emissions

Gases emitted by combustion processes have not been dealt with by legislation to the same extent as particulate matter. There is, however, a considerable effort being made presently to control the emission of gases. Undoubtedly restrictions in the future will become ever more stringent. Any combustion process will produce, under the best of conditions, large quantities of carbon dioxide and water, and there is presently no thought on the part of any regulatory agencies to any way control the amount of these gases emitted. It is entirely conceivable, however, that someday society will be sufficiently concerned about carbon dioxide build-ups to give further thought to the emission of this gas to the atmosphere. When combustion is not perfect, then, of course, carbon monoxide may be found. Although this gas is toxic, most incinerating installations would not produce significant amounts, primarily because the gas is also combustible and every effort will be made to burn it to maximize the amount of heat produced. If, for some reason, combustion is not as efficient as it might be, then carbon monoxide emissions could be of significance and would require some degree of control, probably by combustion after the main combustion chamber. It is also possible to produce various light hydrocarbons by combustion or by distillation from the fuel after introduction into the combustion chamber without adequate time to completely burn such hydrocarbons. In general, such emissions would be severely limited by existing regulations and elimination by after-burning would be required.

Assuming that combustion is complete, it is still probable that the gases sulfur dioxide and nitrogen oxides (NO_x) will be produced in quantities sufficient to be of concern. The amount of sulfur dioxide, or more correctly, sulfur dioxide plus sulfur trioxide (SO_x), is directly proportional to the sulfur content of the sludge, and this may vary considerably depending upon the nature of the sewage. If the sulfur content of the sludge were as high as 1%, some control measures would have to be taken to reduce the sulfur dioxide emissions. Unfortunately, the existing state of the art is such that sulfur dioxide removal is difficult, expensive and somewhat uncertain. There is very great interest in this problem, however, and a great amount of research in progress which undoubtedly assure workable methods becoming available in the short-term future. It might be much more attractive in the case of sludge to somehow minimize the sulfur content of the effluent material, rather than to attempt to remove sulfur dioxide or sulfur oxides from the stack gases.

Nitrogen oxides can result from two different processes, first of which is the combustion of any material with the attainment of sufficiently high temperatures to oxidize some of the nitrogen in the air. Thus, it is highly probable that any sludge incinerator will produce some NO_x, the quantity of which will be proportional to the temperature of combustion and other factors affecting the combustion process. In addition to this source of NO_x, however, the combustion of nitrogenous materials in the sludge will further yield NO_x and it is possible that such materials could be present in sufficient quantities to cause a very serious NO_x emission problem. Present regulations are in the formative stage, but definitely call for the reduction of NO_x to certain levels, which would then require some means of removing these gases from the stack effluents. However, the removal or reduction of NO_x from stack gases must be considered an engineering problem which has not yet been fully solved.

But again, in view of the increasing stringency of federal regulations, a considerable amount of research is underway and will doubtlessly produce satisfactory devices for future use.

An additional class of compounds which might be troublesome are those containing a halogen, most commonly chlorine. If the sludge contains an appreciable amount of such compounds, they may burn to form acidic substances such as hydrochloric acid or phosgene, which are toxic, irritating and corrosive. Most inorganic chlorides would not likely form such compounds and might well instead remain as salts in the ash, but organic compounds, which contain chlorine and the ubiquitous vinyl, will burn to produce the acidic decomposition products previously referred to. In any incineration system where such materials are burned, it is necessary to install scrubbers, usually containing alkaline solutions, to remove them. The necessity for such scrubbers depends upon the expected nature of the sludge, and would probably be determinable by pilot testing.

While mercury vapor is not expected to be emitted at levels which would impose a direct human health hazard, there is a possibility that very small quantities of certain metallic oxides and known carcinogens, such as benzo-a-pyrene, are implicated in elevated incidences of lung cancer. Should further research verify a relationship between other forms of cancer and effluents produced by incineration, the virtual elimination of particulate emissions could become necessary, although at substantial cost.

The disposal of incinerator residues and collected particulate matter should create no hygienic problems to the general population, providing that established guidelines for selecting disposal sites and maintaining quality control are followed.

In the incineration of sludge and the eventual land disposal of sludge ash, there are potential occupational health problems which may result from high exposure to these materials. These problems, however, are not expected to be of great magnitude nor to

pose any unusual monitoring difficulties.

In view of the unknown nature of the substances in sludge, it must be considered a possible source of yet other compounds, not commonly encountered. Hence, the pilot study program should include exhaustive studies of typical emissions with analysis by such sophisticated means as mass spectography and gas chromatography combined, for the purposed of detecting unsuspected and possibly highly toxic gases. Should any such substances be found, it would be necessary to appraise their potential and determine whether measures taken to control or remove other gases would also be satisfactory for the more exotic materials.

VI. Some Potential Health Hazards Facing Employees in Wastewater Treatment Plants

While each class of air pollutants will be discussed in turn, a brief explanation of threshold limit values might be in order here. Threshold limit values (TLV's) refer to "airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect" (65). It should be remembered that the TLV of a substance is quite distinct from its LD_{50} (the dose which is lethal to 50% of the experimental units). That is, TLV's do not require the demonstration of death as a prerequisite for calculation. The Occupational Safety and Health Act of 1970 provides for the establishment of standards for substances and these will eventually replace the TLV's.

The wastewater treatment plant employee has maximum exposure to wastewater and, hence, faces all of the potential health problems associated with these plants at a much higher level of risk than does the general population. It appears, however, that, despite this high level of exposure to the potentially dangerous infectious and chemical agents of raw sewage, the actual incidence of infectious

and parasitic disease may not be very high. While there are a few incidences of contracting infectious hepatitis to workers, much more information is needed in order to effectively evaluate these hygienic impacts (3). Certain biological hazards have been considered in the discussion of aerosols.

According to an in-service training course on safety practices in water and sewage works at the University of Michigan (66), an effective occupational safety program in a public utility depends upon recognition of potential hazards, followed by a concerted effort to minimize danger by correcting these hazardous conditions. Most discussions of safety point out the similarities between operations in water and wastewater works. While, in many respects, these two utilities are similar; wastewater, however, can be a much more dangerous mixture to handle. As a result, safety practices which are recommended for both operations may be critical in wastewater treatment because of the greater risks involved.

Data compiled by the National Safety Council shows that employees in water utilities sustained disabling injuries at a rate of 1.8 times that of gas utility employees, 2.5 times that of electric utility employees and 19 times that of communication employees. The Kansas City Water Department reported that 31 per-cent of their yearly injuries resulted from handling objects, while 13 per cent came from falling objects. Of these injuries, 43.2 per cent were listed as bruises, contusions, cuts or lacerations; 28.4 per cent were sprains and strains, and 10.8 per cent were fractures. As in any other industry, accident prevention must begin with good record keeping so the hazardous conditions can be identified and corrected. For purposes of this discussion, safety in water and wastewater works will be divided into three major headings: gas, vapor, and fire hazards; chemical hazards; and safety in plant operation.

Gas, vapor, and fire hazards

The hazardous gases which are most likely to be found in water and wastewater systems are chlorine, sulfur dioxide, hydrogen sulfide, ammonia, carbon dioxide, and sewage gas. Sewage gas includes sewer gas and digester gas. Methane and carbon dioxide are the major components of sewage gas, making it a potentially explosive mixture. In addition, gasoline and petroleum vapors are sometimes found in wastewater, a result of indiscriminate dumping in the sewer system, accidental spillage on the streets, or leaking from storage tanks.

Chlorine is used in both water and wastewater treatment for disinfection. As has been mentioned, while gaseous chlorine (Cl_2) has a TLV of 1 ppm, it is rapidly lethal in concentrations which exceed 1000 ppm. The threshold odor concentration may range from .3 ppm to 3.5 ppm, well below the lethal level but possibly above the TLV. Any plant which uses chlorine must be equipped with suitable chlorine gas masks to protect employees and a well-practiced emergency plan to deal with chlorine leaks. Chlorine will be discussed further under the subject of chemical hazards.

Hydrogen sulfide is easily recognized by its characteristic rotten eggs odor, but it quickly deadens the sense of smell. The level of hydrogen sulfide in wastewater depends mainly on the strength and age of the waste and on the amount of sulfur in the area water supply. Hydrogen sulfide has a TLV of 10 ppm and is rapidly lethal at 1000 ppm.

Ammonia may be present in sludge filter rooms in wastewater plants, and is also used in some water treatment plants to help establish a combined chlorine residual in the finished water. It is explosive when mixed with air in a concentration of 15-28 per cent by volume. Ammonia gas is irritating to the skin at a concentration of 1.5 - 2.0 per cent within 15 minutes (1972 TLV: 25 ppm). Any facility using ammonia must be equipped with gas masks, rubber gloves

and suits as well as safety showers to protect the employees.

Carbon dioxide is non-explosive, but it presents a respiratory hazard. It is heavier than air and tends to collect in manholes, wells, sewers, etc. In such places it can displace the air and create an oxygen-deficient atmosphere. A carbon dioxide concentration of 10 per cent can be tolerated briefly; 12-15 per cent causes rapid loss of consciousness. Adequate ventilation is essential to prevent dangerous conditions from developing. It has a TLV of 5,000 ppm.

Carbon monoxide is of some concern as an explosive, but the major danger arises from its behavior as an asphyxiant. Carbon monoxide (TLV: 50 ppm) has 300 times the affinity for hemoglobin in red blood cells as does oxygen. It is dangerous in one hour at 0.15 - 0.20 per cent in air and is fatal above 0.4 per cent. Again, ventilation is the key to accident prevention.

In general, the dangers from fires at water and wastewater plants are not great, but the danger of explosion always exists. This is especially true in wastewater treatment. The danger points for fires are storage rooms, workshops, laboratories, screen rooms (where petroleum vapors may gather), and digesters where the methane from sewage gas can create an explosion and fire hazard. Activated carbon is a fire hazard, especially when stored in bulk bins. The carbon dust can create a potentially explosive condition in the storage area. Carbon fires are difficult to detect and control because they burn with an intense, colorless flame. Prevention of fires is best accomplished through good general housekeeping; use of explosion-proof electrical equipment; careful attention to design criteria such as placement of doors, separation of plant heating units from the rest of the buildings, and proper distribution of effective fire extinguishers.

Chemical hazards

Chemical hazards are encountered mainly in two places in the

plant: in the laboratory and in the treatment works. The subject of laboratory safety is too broad to discuss in detail, but all operators must be aware of the possible hazards involved in lab work. Although the lab may be small, good lab practice must be followed to avoid personal injury.

In water treatment, chlorine is probably the most dangerous chemical used. Caution must be exercised in handling and storage of liquid chlorine containers. Any suspected leak in a chlorine system must be investigated, because the corrosive action of chlorine in water will invariably make the leak larger. Adequate caustic solutions must be readily available to absorb the contents of a leaking chlorine container. All employees who may have contact with chlorine must be made familiar with the use of protective masks and other equipment and the first aid measures to help anyone injured by chlorine.

The general rules for chlorine handling also apply to sulfur dioxide, carbon dioxide and ammonia. In each case, protective equipment must be readily available and employees must be skilled in its use.

Quicklime (CaO) is widely used in water and wastewater treatment. As a dry powder it is an irritant to the skin, eyes and lungs. Quicklime liberates large amounts of heat when it comes in contact with water and indiscriminate storage or disposal can create a fire hazard. Certain other chemicals used in treatment works, such as ferrous sulfate, aluminum sulfate and ammonium sulfate can form explosive or highly corrosive mixtures with quicklime.

Safety in plant operation

As in other aspects of plant safety, common sense and a safety-oriented staff are fundamental to safety in plant operation. This discussion includes some of the basic considerations.

Proper access to equipment will reduce danger from falls, a major source of injuries in treatment plants. Since most plants are

multi-level buildings, ramps, stairs, and ladders must be well designed, lighted and properly located. All moving equipment must be shielded with some type of guard, screen or fence to prevent entanglement, falls and electrical shocks. All portions of the plant and grounds should be well-lighted and provided with emergency power sources.

The dangers from concentrations of explosive or toxic gases can be prevented by proper ventilation. Windows, door louvres, freshair intakes, forced draft fans and portable air blowers can all be used in combination to prevent hazardous conditions from developing. Whenever employees enter manholes, pits, digester control and sludge pumping rooms, or wet wells, portable ventilation equipment must be used to ventilate the area, and the atmosphere must be tested for explosive or oxygen-deficient conditions.

Identification of pipes and lines is essential in treatment plant operation. Proper identification of water sources will prevent inadvertent cross-connections, for example. High voltage, pressure or steam, hot water, sewage or sludge, gas and chemical lines must be well labeled to prevent hazardous conditions from developing.

Electrical hazards have been mentioned elsewhere, but it should be emphasized that explosion-proof fixtures and equipment must be used wherever gases may concentrate. Sewage and digester gases are obvious hazards, but dust from activated carbon, petroleum vapors in screen rooms and many other potentially explosive gases may be present in the plant.

Finally, the personal health of the employees must be protected by supplying them with sanitary lunchroom facilities, locker rooms, storage rooms for personal belongings and other safe facilities. The personnel must be drilled in the use of safety equipment and made aware of the proper operating procedures which will protect them from personal harm.

VII. Comparison of Alternative Systems Relative to Hygienic Acceptability

A. Matrix evaluation of basic disposal methods

Four basic systems of sanitary and industrial wastewater treatment (current secondary wastewater treatment with activated sludge, proposed advanced wastewater treatment, proposed independent physical-chemical treatment, and proposed treatment by land irrigation) were compared for relative overall hygienic acceptability (Table III-A). Likewise, the proposed methods of stormwater treatment (treatment by irrigation and independent physical-chemical treatment) were compared in a similar manner (Table III-B). It should be noted that these comparisons resulted from independent ranking, of the relative desirability of each method from a hygienic viewpoint by each of the participants of this study, and subsequent consensus. While a wide range of factors were considered in rating these methods, it should be realized individual expertise and experiences of the evaluations exerted a significant influence upon the evaluation.

B. Evaluation of alternative wastewater management systems

Each of the eleven alternative wastewater management systems as proposed by the Corps of Engineers is subject to the hygienic advantages and disadvantages of each of the component methods of treatment and sludge disposal which compose that system. Since a thorough evaluation of each of these proposed systems would be extremely repetitious of the above contents of this report, an effort will be made to make brief comments on some aspect of the system which might be unique or which should be subjected to further consideration.

1. Advanced Wastewater Alternative One:

This alternative should yield an effluent which presents a minimal health hazard. Consistent precautions in the handling of sludge which will be dewatered and landfilled should reduce health hazards.

TABLE III.

MATRIX EVALUATION OF BASIC DISPOSAL SYSTEMS IN ORDER OF RELATIVE HYGIENIC DESIRABILITY (i.e. 1 = MOST DESIRABLE; 4 = LEAST DESIRABLE)

A. Sanitary & Indust. Sewage	Reduction of Potential Infectious Agents		Reduction of Potentially Hazardous Chemicals		Potential Health Impact on In-plant Employees	Relative Potential Impact on Hlth. Surrounding Pop.			Potential Annoyance Odor Emission
	Effluent	Sludge	Effluent	Sludge		Efflu.	Sludge	Air	
Secondary Treatment	4	3	4	3	3	4	4	3	3
Physical-Chemical Treatment	2	1	2	2	1	2	2	1	1
Advanced Waste Water Treatment	1	2	1	1	2	1	1	2	2
Land Disposal Treatment	3	4	3	4	4	3	3	4	4
B. Stormwater									
Land Disposal	2	2	1	2	2	2	2	2	2
Physical-Chemical Treatment	1	1	2	1	1	1	1	1	1

* For purposes of this evaluation, sludge disposal for secondary treatment, IPCT, and AWT is assumed to be by incineration with landfill disposal of ash.

2. Advanced Wastewater Alternative Two:

The effluent from this alternative should be similar to that of AWT-1 and, with the utilization of adequate air pollution control devices, the incineration of sludge should present a minimal health hazard.

3. Independent Physical-Chemical Treatment Alternative One:

This alternative may be expected to yield a high quality effluent and, with proper air pollution control devices, sludge incineration should present a minimal health hazard. However, concentration at a single site of massive quantities of hazardous materials constitutes a great risk.

4. Independent Physical-Chemical Treatment Alternative Two:

This alternative should be very similar to IPCT-1 with the added advantage that the increased number of treatment plants may decentralize detrimental health effects should one of the systems lose its efficiency.

5. Independent Physical-Chemical Treatment Alternative Three:

The disposal of dewatered sludge by landfill should pose a minimal health hazard.

6. Land Irrigation Treatment Alternative One:

The treatment of all sewage and stormwater by land irrigation would present maximum exposure to specific risks which have been outlined in this report. The effluent may be expected to be of very high quality.

7. Land Irrigation Treatment Alternative Two:

This proposal would involve a much larger area of land for sewage spray irrigation (not including stormwater), thus increasing the risks of potential exposure to downwind drifts of aerosols. But these risks may be partially offset by exposing fewer individuals, due to the lower population of these areas and by confining land treatment of stormwater to a smaller area.

8. Combination Wastewater Treatment Alternative One:

The effluent from this AWT and IPCT combination can be expected to be of very high quality. Sludge disposal methods by dewatering and landfill, with necessary precautions, should present small potential public health hazard. Controlled incineration at Monroe should pose minimal problems.

9. Combination Wastewater Treatment Alternative Two:

This alternative, which is very similar to Comb.-1 except that this method employs sludge incineration at both Wyandotte and Monroe, can be expected to pose minimal health problems as long as adequate air pollution control devices are employed.

10. Combination Wastewater Alternative Three:

This combination of AWT, IPCT, and Land Treatment would be similar to Comb.-2, but with increased localized land application of both sewage and stormwater. Since land irrigation sites would be used only by those service areas which are in close proximity to these sites, the reduced wastewater load for land treatment should reduce the potential health hazards which might be present with Land 1 or 2.

11. Combination Wastewater Treatment Alternative Four:

This alternative, which would employ AWT or Land for sewage disposal and PCT or Land for stormwater disposal, should provide a high quality effluent but the potential health risks which might be associated with land disposal would be increased over that of Comb.-3.

VII. Summary and Conclusions

An assessment of some of the potential hygiene impacts of the Army Corps of Engineers proposed alternative methods of wastewater management in Southeastern Michigan was made. Consideration was given to some of the potential infectious and non-infectious pathogens which might be found in wastewater, to disinfection processes, and to

some present and future residual levels of affected streams prior to the consideration of each of the alternative systems.

The basic proposed methods of wastewater management include advanced wastewater treatment (AWT), independent physical-chemical treatment (IPCT), and land treatment. The proposed alternative wastewater management systems include various combinations of these specific methods of wastewater treatment with varied methods of sludge disposal. The individual methods of treatment were assessed for their reliability relative to the reduction of potentially hazardous biological and chemical agents and for problems which might be unique to each particular process. Some potential health hazards to wastewater treatment plant employees were examined and specific considerations were made concerning sludge disposal.

A relative comparison of alternative methods of wastewater management from a hygienic viewpoint was made. The participants ordered the hygienic desirability of each method as follows: 1) Advanced wastewater treatment, 2) Independent physical-chemical treatment, 3) Treatment by land irrigation (these are ranked from most desirable to least desirable). In a similar manner, the hygienic desirability of alternative methods of sludge disposal is ranked as follows: 1) Incineration of sludge, 2) Landfill of dewatered sludge, 3) Agricultural use of sludge.

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